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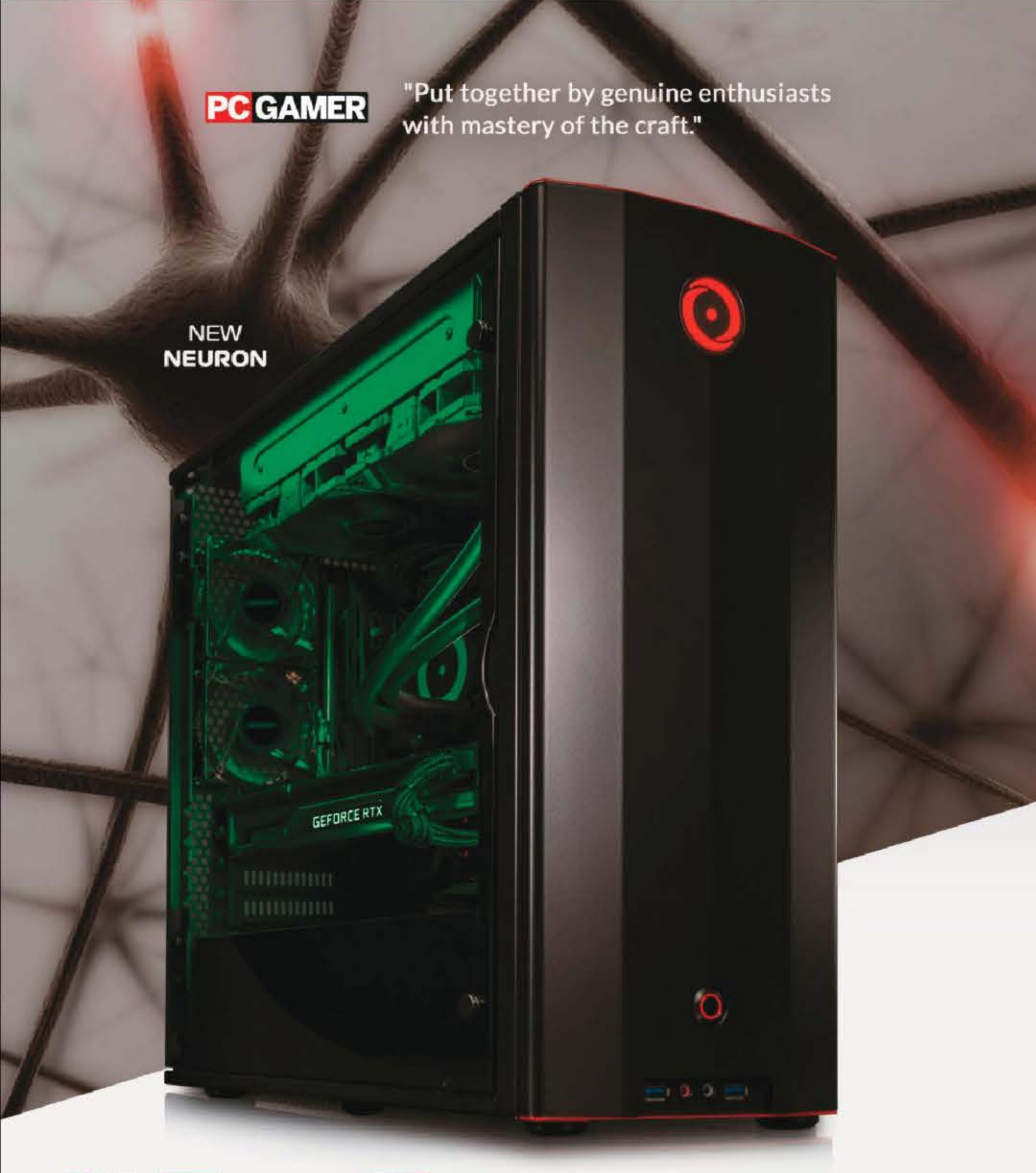

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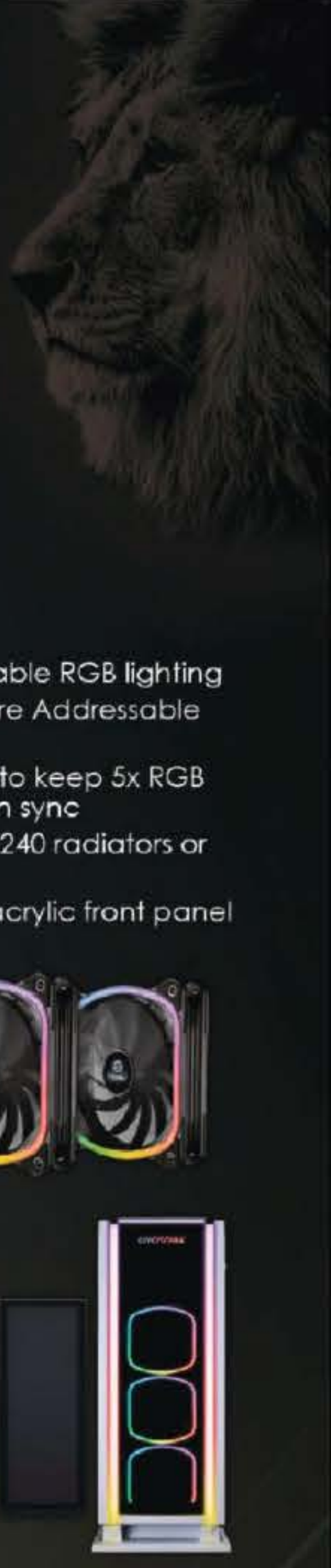

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Alan Dexter

WHAT A YEAR IN TECH!

WHAT AN INCREDIBLE 12 months we've just experienced. 2017 pushed the PC forward at a stunning rate, and 2018 hasn't eased back at all. We've had second-gen Ryzen, Intel's ninth-gen chips, and then the small matter of Nvidia's new graphics cards. On top of that, we've had some incredible SSDs, a whole swathe of quality peripherals, and some of the best chassis to ever grace our humble systems. For a full rundown of the best hardware, and there's been a lot, turn to page 24.

One piece of hardware missing from this feature is monitors, because we've dedicated a separate article to the subject. Screen tech has also bounded on at an alarming rate, and knowing what it all means, and what sort of screen is for you, is even more complex. Which is why we break down the underlying technologies and offer recommendations for a range of uses and budgets. Read more on page 36.

If you are in the market for upgrading, there's a good chance you'll be moving over to a new, faster SSD. But what's the best way of copying your old OS to your new drive? Turn to page 48 to find out.

This issue, we welcome a new team member, Joanna Nelius. Joanna joins us as a hardware staff writer, and you'll see more of her words in coming issues. I hope you'll join me in welcoming her.

Alan Dexter is Maximum PC's *executive editor and a punisher of hardware. He's been a tech journalist for over 20 years, and has no problem upsetting the PC industry as a whole.*

↘ submit your questions to: comments@maximumpc.com

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THE NEWS

Apple's Serious New Tablet

Latest iPad Pro is faster than your laptop (probably)

APPLE DOESN'T have a particularly hectic release schedule—some of its gear is untouched for years—but when it does make a major revision, people take notice. Whatever your views on Apple, it makes tantalizingly desirable stuff. It's just launched a refreshed MacBook Air and Mac mini, but the star of the show is a brand new iPad Pro. It's thinner, lighter, and much faster.

The new iPad Pro comes in two sizes—11 and 12.9-inch—and the display goes that little bit closer to the edge. Its Liquid Retina screen first appeared on the iPhone XR. It's not OLED, but as LED screens go, it's good, boasting the most accurate colors of any in the business, and a 120MHz refresh rate. A 12MP camera faces outward, capable of 4K 60fps video, and a 7MP camera with TrueDepth faces the other way, which you need for the Face ID logon, which also comes over from the iPhone. There's a new Pencil, too, which magnetically snaps to the case to recharge.

All good stuff, but it's inside that we get the main upgrade: the A12X Bionic SoC, with eight cores, and seven GPU cores. It's built using a 7nm process, and sports 10 billion transistors (an Xbox One's SoC has half that). It also has an eight-core neural engine for real-time machine learning. All this adds up to a 35 percent improvement in single-core performance, and 90 percent in multicore over the stock A12.

Apple is being bullish about performance, claiming it makes the iPad Pro "more powerful than most computers" and "faster than 92 percent of all portable PCs." Bold stuff, but it isn't far wrong if early tests are to be believed. It was demonstrated running Photoshop without a stutter, and graphical performance is likened to an Xbox One S. The performance is roughly on a par with a MacBook Pro sporting a Core i7-8750H. So it's quick. Battery life does take a bit of a hit, though, as it's quoted at 10 hours.

Can the new iPad replace the laptop? The launch event made constant comparisons, but the short answer is no. It's still a tablet, and doesn't offer a consistent experience with full systems. To replace a laptop it needs the same OS, a trackpad, and be easily expandable. Nice try, but we are unconvinced.

We know that when Apple gives with one hand, it takes away with the other, often by removing ports we were using. There is no Lightning port, and out goes the Home button. All you get is one USB-C port, and that doesn't support external storage. You can't plug in so much as a flash drive without third-party help. So, none of your old iPad accessories work, and you can't use cheap external storage. You need an adapter to connect non-Bluetooth headphones, too, so you're stuck with the built-in speakers until you do.

The next problem is a hefty one. The 11-inch model starts at $799, and the 12.9-inch one at $999. If you start playing with the configuration, it can reach $1,899. If you want 4G cellular connection, for example, it adds $150. You'll probably also want the new $129 Apple Pencil and $179 Smart Keyboard Folio. Ouch.

Slipping out alongside the iPad Pro is a new MacBook Air, also thinner and lighter, with a new 13.3-inch 4K screen. You can now log on using Touch ID, and it keeps two Thunderbolt 3 ports. Prices start at $1,199, and run to $2,599. Also refreshed is the Mac mini. This gets more capable insides, faster processors, more memory, and storage. It still has a good set of ports, too, including Thunderbolt, USB 3, and 3.5mm jack. Prices start at $799 and run to over $4,000.

Apple undoubtedly makes lovely gear; the new iPad is pretty close to awesome, but all this svelte power is crushingly expensive. Quite who needs such power in a tablet is questionable. How often have you needed to run Photoshop on a small screen without a mouse, when out and about? Yep, those creative types Apple seems so keen to impress. It is a beautiful halo product, though. Of more interest is that A12X chip: Mobile does not necessarily mean slower anymore. **–CL**

03
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> "Apple's new iPad Pro is beautiful, fast, and painfully expensive.

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WINDOWS 10 UPDATES STILL A MESS

October deadline missed, more bugs found

MICROSOFT SET ITSELF a goal of two major updates to Windows 10 a year, and it's already gone wrong. The October update appeared, then was quickly pulled. It had a nasty habit of emptying people's My Documents folder. It transpires that if you designated a My Documents folder on another drive, the update would clean out the original. A fixed version was readied, but that developed a bug of its own. The Unzip app proved erratic, replacing all the files with the same name without asking, or simply failing altogether.

Fingers are being pointed at Microsoft's testing process. In 2014, it moved much of this to third parties. The new structure was modern and smart. Waterfall development was out, and Agile was in. No more passing a project down through the line, from requirements, to design, to implementation, to verification. The new way opened Windows development out to the world with its Insider Program, with over seven million members.

All well and good, but the cracks are starting to show. Testing an entire OS of the complexity of Windows is serious undertaking. So many testers create a lot of noise, and not all of the feedback is high quality. To test something properly, you really need to know how it works in the first place. Simply adding more people to the Insider Program won't help either. The file deletion bug was spotted by more than one tester, and reported in forums, but the right people didn't get the message. The reports were buried under a mountain of other feedback.

Two major updates a year at specified dates has given Microsoft a hard target that invites the company to over-reach. We like new features, for sure, but we like stable and secure updates much, much more than that. **–CL**

RTX 2080 TI CARDS DYING

IS THE FLAGSHIP CARD TOO HOT?

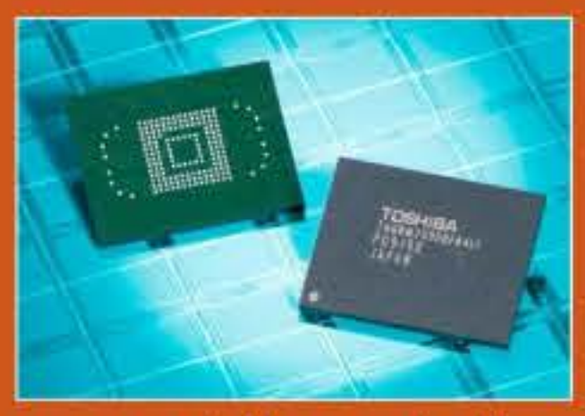
NVIDIA'S GEFORCE RTX 2080 TI, the company's latest and greatest graphics card, has picked up a less enviable reputation: Reports are growing that a noticeable number of them are failing. At $1,200 each, there is understandable anger.

Nvidia claims that "it's not an increasing number of users," and it is "working with each user individually." Suspicion is focused on the memory overheating under prolonged heavy load. Two GDDR6 modules sit right over major power tracks. Some cards have recovered themselves after cooling down, so a thermal issue looks likely.

How serious is this? It's difficult to tell; a small number of people can make a lot of noise thanks to the Internet. If this does prove to be overheating memory modules, it is relatively easy to fix, but how it got through testing is another matter. **–CL**

CHEAP SSDS ON THE WAY

Oversupply pushing prices down



PRICES FOR NAND memory have halved this year, and some sources are forecasting another halving of prices in 2019 (DigiTimes, for one). The solid state memory market has seen healthy growth, and prices have been fairly steady for years, but manufacturing capacity has more than kept pace, and now over-capacity looms.

The main reason is 3D NAND tech, which increases data densities. You can get more memory from the same wafer; 64-layer chips are commonplace, and 96-layer is on the way from Samsung and other big players. Toshiba has a large fabrication plant coming online next year, too. Some stagnation in the smartphone market is also being cited, as people upgrade less often.

The price drop has trickled down to SSDs; 500GB drives are now about $50 cheaper than they were six months ago. As the 64-layer chips take off, we can expect capacities to rise, and prices to fall even further. **–CL**

Tech Triumphs and Tragedies

A monthly snapshot of what's good and bad in tech

TRIUMPHS

HUBBLE FIXED
NASA appears to have fixed the telescope's gyroscope by going old-school—shaking it about, and turning it off and on again.

ARTIFICIAL MOON
Forget street lighting, the Chinese city of Chengdu plans to use a reflective satellite 300 miles up instead.

STEAM GAMES GO LINUX
Valve has 2,663 games running under Linux, using Proton, a modified version of Wine.

TRAGEDIES

APPLE WATCHES KILLED
The watchOS5.1 update turned rather a lot of Apple watches into mere jewelry—it's been pulled and replaced.

TWITTER IS OLD-HAT
There's been no growth for three years, and now it's falling; the teenagers have moved on.

FACEBOOK PORTAL SPIES
Despite early denials, it transpires that the Portal does collect data to target you with advertising. Of course.

Break DRM Legally

KEEPING OLD SOFTWARE and hardware going can be problematic, thanks to Digital Rights Management, but help is at hand from the Library of Congress. Every three years, it carries out a copyright exemptions review; this year, it's decided that hacking DRM to repair or maintain hardware is legal. The last review, in 2015, included tractors as an example of what could be legally hacked, after farmers complained at John Deere's tactics to prevent home maintenance. This year, it has widened the scope to include more devices, making it OK to circumvent hardware and software designed to stop you altering your legally acquired consumer electronics. So, you can crack open a smartphone or laptop, bypass the protection, and repair or customize.

It applies to software, too, useful to keep abandoned online games running. San Francisco's Museum of Art and Digital Entertainment tries to keep many old games going as part of its exhibits, and has campaigned for changes to the law. There are limits, though: You can't make hacked games publicly available, for example. You may have the right to try to change or fix something, but the manufacturer still has no limit on how difficult it can make this. It doesn't have to supply spare parts either.

There are other signs of change. Motorola has become the first phone company to sell repair kits to enable you to fix its phones at home. The kits are mostly battery and screen-replacement ones, and include all the specialist tools you need. The Federal Trade Commission has also handed out warnings to Microsoft and Sony that they can't tell people that opening their consoles voids the warranty. It doesn't. **–CL**

***Star War Galaxies,* left to die by its publisher—you can now legally circumvent its DRM.**

Oculus Rift 2 Canned

VR pioneer Oculus has canceled its Rift 2 headset, which was to have been a complete redesign of the original. The company also saw the departure of one of its co-founders, Brendan Iribe, apparently over fundamentally different views on the Rift's future. Oculus is part of Facebook, and it wanted a more accessible headset that didn't need a high-end PC. It seems Iribe, head of the Rift 2 development team, didn't agree.

A new Rift is being developed still, expected early next year. It'll be a more modest upgrade, losing the external tracking, which is tricky to set up, but accurate. It looks as if Facebook wants to focus on sales over the experience. **–CL**

IBM buys Red Hat

IBM is to spend $34 billion to buy the firm that brought us Red Hat Linux, but which is also heavily involved in open-source cloud software. As IBM's CEO Ginni Rometty said, "It changes everything about the cloud market. IBM will become the #1 hybrid cloud provider." Linux hardly features in the deal at all.

IBM has some ground to catch up on. Microsoft and Amazon are heavily invested in cloud services; it's Internet services that make Amazon money, not the shopping. Red Hat has extensive experience in this, and a customer list that generates hundreds of millions through subscriptions. This purchase shows where IBM thinks the power lies: in the clouds. **–CL**

FLEXIBLE PHONE LANDS

Royole FlexiPai beats big players to market

WE'VE BEEN PROMISED flexible phones since 2011, and have seen impressive working prototypes from Lenovo and Samsung, but everyone has been beaten to market by Royole, with the world's first commercial foldable phone. The company was started in 2012 by engineering graduates from Stanford, and has become a leader in thin and flexible displays.

The FlexiPai is a fairly heavy (0.7lb) and chunky device, with one fold in the middle. It transforms from a 7.8-inch tablet with a resolution of 1920x1440 into a dual-screen phone, with a third screen along the spine. Otherwise, it's a full-featured smartphone, complete with dual high-res cameras. Power comes from a Qualcomm Snapdragon 8150 processor, and it runs Royole's own Water OS, a fork of Android 9.0. Royole says the screen is "virtually" unbreakable, and has been tested to over 200,000 flexes. It's not cheap, though—a Chinese version costs about $1,300, with 128GB of storage, and 6GB of RAM. Developer versions are available globally, but it's unclear which markets will get an official launch. Using a custom OS is not ideal, although Alphabet is working on a version of Android for flexible phones.

Royole may be first, but the big players aren't far behind. Samsung's folding phone was first shown in concept in 2013; it's due to be unveiled any moment now, although it's unlikely to be on sale until next year. Lenovo has been showing working prototypes since 2016, and can't be far behind. LG has invested $1.7 billion in new flexible screen production lines, and is rumored to be unveiling its phone in January. Huawei is expected to launch its offering within a year, too.

Cell phone formats have been through a few changes, from bricks down to tiny flip phones, then back up in size to large slabs, and now, it seems, into folding tablets. The FlexiPai is an interesting start, with more polished examples to follow soon. **–CL**

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Jarred Walton

TECH TALK

Nvidia's RTX Multi-GPU Shifts to NVLink

THE DUST FROM THE TURING launch has settled, and we're left with the most expensive consumer GPUs in Nvidia's history. The RTX 2080 Ti takes over where the Titan Xp left off, with a decent increase in performance. Most of us would be happy with that, but the extreme performance crowd always wants more, and Nvidia has supported that pursuit with multi-GPU SLI technology dating back to 2004. But that's not the whole story.

SLI has a long history, going back to 3dfx's original SLI (Scan-Line Interleave), where two Voodoo2 cards could render alternate lines. Nvidia acquired 3dfx's assets in 2004, and began offering a new SLI (Scalable Link Interface) with the GeForce 6800 family. Instead of alternating rendered lines, Nvidia's GPUs used alternate frame rendering (AFR). It was a significant change in functionality, and has led to a host of issues over the years.

SLI systems—and AMD CrossFire PCs—render multiple frames sort of simultaneously. The drivers need to balance things so that frame pacing is relatively consistent, or you get microstutter and other problems. Ideally, with two GPUs, GPU1 starts the first frame, and GPU2 starts work on the next when GPU1 is halfway finished with its frame.

Nvidia later introduced three-way and four-way SLI, but the difficulty of maintaining consistent frame pacing, the additional latencies, and limited scaling in games made them niche solutions that were more trouble than they were worth. Nvidia killed off three-way and four-way SLI with Pascal. With Turing and the RTX 2080, two-way SLI is the only supported mode, but there's a second change.

Pascal GPUs introduced the HB SLI bridge, which increased SLI link bandwidth from about 1GB/s to 4GB/s. That was necessary to better support 4K60 resolutions, but it still wasn't enough—not with 4K144 HDR and 8K displays now available. So, Nvidia moved to an NVLink connector for the RTX 2080 and 2080 Ti. The 2080 gets a single NVLink channel that's good for 50GB/s, while the 2080 Ti has two and 100GB/s. Thanks to the higher bandwidth, there's no difference between running dual GPUs off x16 PCIe connections versus dual x8 connections, which is good, as the Core i7-8700K and i9-9900K end up being faster in games than any X299 enthusiast platform CPU.

RTX 2080 Ti cards in SLI use Nvidia's high-speed NVLink bridge.

But how does RTX 2080 Ti SLI perform? Results vary. 3DMark shows nearly perfect scaling in Time Spy Extreme and Fire Strike Ultra. *GTA5*, *Rise of the Tomb Raider*, *Strange Brigade*, and *The Witcher 3* also show excellent scaling of 80 percent or more at 4K. Other games, such as *Battlefield 1*, *F1 2018*, *Far Cry 5*, *Rainbow Six Siege*, *Shadow of the Tomb Raider*, and *Shadow of War*, aren't so impressive, but manage 30–50 percent scaling. Then there are games that show negative scaling: *Assassin's Creed*, *Call of Duty*, *Divinity Original Sin*, *Hellblade*, *Hitman*, *Monster Hunter World*, *Prey*, *Wolfenstein*, and more.

As a $2,500 proposition ($1,200 per 2080 Ti and $79 for the NVLink adapter), this isn't for the faint of wallet. It's also sobering to think that even 4K isn't enough to max out scaling from SLI. Beyond that, we're years away from 8K gaming being a viable choice. That's all for the best as far as I'm concerned. When SLI or CrossFire work well, they're impressive, but far too often, you run into incompatibilities or glitches. I'd rather spend my time playing games instead of futzing around with SLI profiles.

Jarred Walton has been a PC and gaming enthusiast for over 30 years.

THE LIST

THE PRICE OF NVIDIA'S PREVIOUS 8 ARCHITECTURES

8

G70 GeForce 7800 GTX ($599)
Nvidia's DX9-supporting behemoth (300+ million transistors) set the bar high for all.

7

TESLA GeForce 8800 GTX ($599)
Tesla employed unified shaders instead of the fixed-pipeline design of its predecessors.

6

FERMI GeForce GTX 480 ($499)
Famously late to the party, Fermi had a lot of work to do, but it delivered where it counted.

5

KEPLER
GeForce GTX 680 ($499)
A power-efficient take on Fermi produced a quality architecture for both desktops and mobile.

4

MAXWELL GeForce GTX 980 ($549)
Nvidia continued to focus on power efficiency with Maxwell. The 970 was a bit of a hiccup.

3

PASCAL GeForce GTX 1080 ($549)
The drop to a 16nm production process helped make Pascal the performance king.

2

VOLTA Titan V ($2,999)
Tensor cores make an appearance, paving the way for deep learning and ray tracing.

1

TURING GeForce RTX 2080 Ti ($999)
Nvidia throws out the pricing rulebook, as it gambles on a ray-traced future.

Alex Campbell

OPEN SOURCE

Big Blue Buys Itself a Red Hat

IBM announced a deal to buy Red Hat at a valuation of $34 billion.

ONE OF THE OLDEST FIRMS in the Linux world, Red Hat, becomes a blue chip company in its acquisition by IBM. The move will pit Canonical against IBM in future battles for enterprise open-source market share. But for desktop Fedora and Ubuntu users, very little will change....

It's difficult to sell something you can get for free. Red Hat managed to do this for nearly two decades. The company took something made freely available—a Linux operating system—and charged a price for it. At the time of writing, International Business Machines just bought Red Hat for $34 billion. That's billion, with a "b."

If you're thinking it's fantastical that one of the oldest companies in computing would buy a Linux vendor for billions of dollars, you're right. Red Hat ceased being a simple OS vendor some time ago.

Sure, Red Hat made its mark by being the premiere Enterprising Linux distribution. A Red Hat Enterprise Linux (RHEL) license bought you support and stability, both of which are critical when running a business. When I was in Iraq, the Blue Force Tracker—an electronic map and messaging system for vehicles that could show where all the other good guys were—ran RHEL. In the consumer space, I often think of Debian or even FreeBSD UNIX as the most stable solution. But when it comes to bulletproof solutions, RHEL is really where it's at.

But selling support for RHEL isn't what makes Red Hat worth 34 billion smackaroons. Red Hat, like Canonical and Amazon, has realized that the cloud is where the real money can be made. Even *Wired* described Red Hat as an "Open-Source Specialist," which is right on the money. Red Hat bet big on projects such as OpenStack and Kubernetes. And from the looks of things, the company has been doing pretty well for itself by becoming the premier enterprise open-source expert.

> I still remember the IBM commercials where narrators talked about how Linux was new and modifiable.

Similarly, IBM has been looking for a way to edge into the cloud business. Amazon, Google, and Microsoft all have big cloud divisions. With large mainframes losing relevance, and its PC business long sold off to Lenovo, IBM made a smart move on betting on open source.

To be fair, IBM has been pro-Linux for a long time. I still remember the commercials where narrators talked about how Linux was new and modifiable, and that the "future was open." A slightly creepy-looking kid was IBM's face of Linux, a caricature of how the OS was always learning new tricks. By buying one of the biggest names, IBM really has embraced Linux.

It's a strange time we live in where IBM is now a services company, and Microsoft loves Linux so much that Redmond is opening up its software patents. Hell, even Linus Torvalds has returned to the Linux Kernel with a freshly minted attitude adjustment.

It leaves one wondering: Is this good for desktop Linux users like you and me? I'm not so sure.

Linux is the most prolific operating system on the planet, but most of those installed instances are on servers and virtual machines. Linux has been great for business because it has lowered the barrier for entry for new companies. But those applications often have little to do with how you and I use computers. Nvidia isn't making better and faster drivers for the sake of gaming on Linux, after all. It's the compute applications of CUDA that are the primary driving force behind driver development. Again, in the Linux world, business comes first. Desktop users generally come second.

In the end, IBM's acquisition of Red Hat will likely have no effect on us as desktop users. Fedora users will still have Fedora, and other distributions will likely continue on as though very little has happened. But in the business world, Red Hat has suddenly become a blue chip company. And if you're Canonical, you're taking notice.

Alex Campbell is a Linux geek who enjoys learning about computer security.

HEAD TO

BY JEREMY LAIRD

DIY Rig vs. Boutique Builder vs. Big-Brand OEM

Do it yourself or pay the man? For some, building your own rig is an essential part of the PC-owning experience. Only by building your own PC can you truly know it. For others, a system engineered by a big OEM can bring technology and features unavailable elsewhere. And what about boutique specialists? Don't they offer a certain attention to detail, and focus on the stuff that actually matters, and hardcore enthusiasts particularly appreciate? Game on.

ROUND 1

Value

Before the commoditization of the PC and its components, the number one reason to build your own PC was to save money. Today? Not so much. Price up a pre-built rig, and compare it to the combined cost of buying its individual components, and the gap is often slim to none. What's more, that comparison usually doesn't take into account "extras," such as an OS and a warranty that covers the whole system.

Of course, home builders may be able to transfer an existing Windows license, or might have a drawer full of spare bits, or be a crackerjack fault-finder. It's also true that if you're patient, and pick up all your components on sale, you can still build something that significantly undercuts both boutique and big-brand pre-built PCs. You can, of course, also source used parts. In extremis, the best value opportunities remain in the DIY arena.

Speaking of pre-built options, the value proposition depends on your preferences and usage. For example, extreme overclocked systems are probably better bought from a boutique outfit, while the big boys tend to be better at shaving the last few pennies off low-end and mid-range systems.

Winner:
DIY

ROUND 2

Reliability and Support

If value used to be the mainstay of the DIY option, reliability and support are the payoff. For starters, even if you buy all brand-new bits, you're only covered for individual items. If you know what's broken, that may be tolerable, but effective fault finding usually requires a box full of spare components for swapping in and isolating issues.

Likewise, what if one component fails and damages another? And what about cross compatibility of components? What if your CPU doesn't like the look of that fancy high-frequency RAM you found on special?

In reality, of course, component failure and incompatibilities are pretty rare these days. But you can't beat the ability to simply ring a number or raise a support ticket, and have your PC replaced or repaired in short order. With that in mind, the comparison between boutique and big OEMs when it comes to support is complicated. If you have a well-recognized fault, the big boys are usually very fast and efficient. If it's something a little harder to diagnose, the ability to speak with a sentient human being at a boutique outfit will be a blessed relief.

Winner:
Boutique and big OEM—it depends on the fault

ROUND 3

Features and Technology

This one really does depend on what you want. There are certain features and technologies only available to each of the three categories. Take any given PC builder, big or small, and you'll be able to find features they don't offer. Only a DIY rig gives you total control over component choice and features.

But that sense of control can be an illusion. If you happen to like the styling and features of, say, Alienware's latest "triad" design Area-51 chassis, good luck "choosing" that for a home build. Alienware doesn't sell it separately. The big boys certainly bring unmatched resources and engineering clout that occasionally translates into something special, which can't be had elsewhere. Similarly, the big brands sometimes have early or exclusive access to the latest and hottest components.

On the other hand, boutique brands are typically more aggressive when it comes to extreme performance or adopting items such as the latest cooling innovations. They're happier operating at the ragged edge with overclocked rigs, while big OEMs are more inclined to cover their behinds in triplicate, and go with proven and more conservative technology and settings.

Winner:
Three-way tie

HEAD

From left to right: *Maximum PC* has form when it comes to DIY builds; boutique brands do some fabulous builds; big-brand engineering is not without charm.

ROUND 4

Performance

How hot are your modding skills? Are you happy hand-tuning CAS latencies? Questions like these determine the performance of a home-built rig. You need to know what you're doing to not only successfully mix and match components and conceive the design of your rig, but also fine-tune the end result. You can match or even exceed the performance of any pre-built PC with your DIY rig, but it's down to you.

You'd think the big OEMs would have an advantage. After all, they surely have access to all the best technology and components, and the engineering clout and resources to combine them in ways that even the best boutiques can't. In practice, however, they are usually if not always quite conservative. They tend to build in relatively big volumes, and are risk averse when it comes to reliability and liability. They similarly aren't usually set up to hand-tune retail systems, so need to pursue more generic configurations.

Boutique outfits are better placed to have an experienced engineer hand-tune a retail rig, enabling them to push the envelope harder, while ensuring each rig is reliable.

Winner:
Boutique builds, unless you really are an expert

ROUND 5

Upgradeability

If you've successfully built your own box, adding future upgrades isn't going to be a problem. What's more, you don't have to worry about voiding the warranty. In those senses, a DIY rig has obvious advantages over pre-built PCs. But there's more. When DIYing, you have full control over the configuration, enabling you to specify certain components, such as the PSU, with a view to supporting future upgrades. The same is arguably true of a good boutique build. The best have future-proofing in mind, and good boutique outfits offer sufficient options to ensure plenty of headroom. Some may even be flexible when it comes to warranty claims, provided any fault isn't associated with an upgrade.

As for the big OEMs, they're dead last in this category. They're more likely to have custom engineering, bespoke motherboards and PSUs, or other design elements that make upgrades difficult. They're also significantly less likely to be accommodating with regard to warranty claims on systems that you've upgraded. That's not to say upgrading a big-brand PC isn't possible, but if upgrades are a primary concern, they're not the best option.

Winner:
DIY

And the Winner Is...

If you have money to burn, and are happy being dictated to by the PC builder, a rig from a big OEM might well be your bag. Certainly, they offer some slick and stylish options that give a very similar actual end-user experience in terms of performance compared to the other options.

But we think DIY and boutique-built PCs are a better choice for the discerning enthusiast, and in terms of the overall proposition, we're calling it a tie. Which you go for comes down to a combination of skill set and preference. The best boutique brands have a very good handle on what a well-informed enthusiast wants. They can likewise work with customers to create something bespoke and on point. And the big advantage is the comprehensive, rather than per-component, support.

On the other hand, for the very last word in personalization, a DIY rig can't be beat. And there's something special about a system built with your own hands; you'll have a closer affinity with it, a better understanding. Like we said earlier, only by building your PC can you truly know it.

DOCTOR

THIS MONTH THE DOCTOR TACKLES...

> Metered Connections
> SSD Solutions
> Buffering Bother

Ultra HD Blu-Rays

Dear Doctor, I've been trying to get Ultra HD Blu-ray discs to play on my system for some time, and finally realized I need a hand from a professional.

CyberLink's UHD Blu-Ray Advisor says I don't have an HDCP 2.2-compatible GPU/display, but Nvidia says otherwise. Perhaps it's the monitor? The utility reports no Advanced Protected Audio/Video Path (GPU). Again, though, Nvidia's specs say my graphics card has this. The CyberLink website claims I need to have my display connected to onboard Intel graphics. Again, if Nvidia already supports the protected path, why would this be necessary?

My hardware includes an Intel Core i7-8700K, an EVGA GeForce GTX 1080 Ti, a Pioneer PIO-BDR-211UBK MAIN-16374 optical drive with Ultra HD Blu-ray support, an Asus ROG Maximus X Hero mobo, and Acer's Predator Z35P 35-inch 21:9 monitor hooked up via DisplayPort. **Jim Pierce**

Not all motherboards support the protected data path needed for Ultra HD Blu-ray playback, but Gigabyte's Z270Z-Gaming 9 does.

THE DOCTOR RESPONDS:
The requirements for Ultra HD Blu-ray playback on a PC are very specific, and mostly intended to keep the path from optical drive to display secure.

Your Pioneer BDR-211UBK disc drive is on CyberLink's list of supported devices. So far, so good. From there, you need a motherboard that exposes Intel's Software Guard Extensions (SGX) in its BIOS, an HDCP 2.2-capable display output, a seventh-gen (or newer) Intel Core CPU with HD Graphics 630 or Iris 640/650, and Windows 10. Not all LGA 1151-equipped motherboards qualify, so consult CyberLink's FAQ [https://goo.gl/YuDtX1].

The idea is to keep data protected when traveling from the optical drive, over the SATA interface, across your chipset, into the CPU for decoding, and out to a display. And by protected, the Doc means that movie studios want to stop their content being ripped. Neither AMD nor Nvidia currently offer this through an add-in graphics card attached to the PCIe bus. Unfortunately, Draconian requirements make Ultra HD Blu-ray playback on the PC more trouble than it's worth, particularly for enthusiasts with high-end desktop CPUs and gaming GPUs.

Cabin Fever

Hi Doc, I have a cabin that I visit every few months, where the only Internet access is a cellular hotspot. My computer there performs a Windows update when I arrive, using up most of my bandwidth allotment. How can I get all the updates ahead of time, put them on a flash drive, and run the cabin PC's update from there, rather than my cellular hotspot? **Jim Henriques**

THE DOCTOR RESPONDS:
It sounds like you need to do two things: prevent Windows 10 from downloading updates over your cellular hotspot, and get Windows updates installed manually.

First, check that Windows knows not to download automatically over a metered connection. Open Windows Settings, click "Devices," scroll down and verify that "Download over metered connections" is unchecked. Next, set the connection between your PC and hotspot

↘ submit your questions to: doctor@maximumpc.com

to metered mode. Click the Wi-Fi icon in your system tray, and select the wireless network you use for Internet access. "Set as metered connection" is deactivated by default. Turn the option on and, if you wish, set a data limit to ensure you stay under your plan's bandwidth cap.

Of course, you'll want to be sure that your PC stays up to date. Microsoft maintains an Update Catalog (www.catalog.update.microsoft.com) with all of its single and cumulative downloads for Windows 10. Press Windows key-R, type "winver," and click "OK" to get the version of Windows installed on your PC. Search Windows support (https://support.microsoft.com/en-us/help/4099479) for a list of newer builds, and download the latest one from the Update Catalog. Be sure to grab the update corresponding to your architecture—32 or 64-bit. Save the file to a thumb drive, then tote it with you on the next trip to the cabin.

The latest definition files for Windows Defender Antivirus can also be downloaded and updated offline. Visit www.microsoft.com/en-us/wdsi/definitions and scroll down to "Manually download and install the definitions."

3D Blu-Ray Backups

Hi Doctor, I have collected a few 3D movies over the years, and have ripped most of my Blu-ray and DVD library to MKV files, loading them on to a Plex server. I own a second computer that is connected to a 3D projector via HDMI, and I watch the movies either on the projector or a TV connected via Roku.

I'm looking for a piece of software able to convert Blu-ray 3D to 3D MKV files, allowing me to watch 2D or 3D movies on the projector. Ideally, I'd like to load the files on to my Plex server, but that isn't a requirement. I already have an application on the second computer able to play 3D MKV files.

David Morton

High-speed DDR4 helps extract max performance from second-gen Threadrippers CPUs.

THE DOCTOR RESPONDS:
Depending on where you live, the software needed to rip Blu-ray 3D media to your hard drive may not be legal to purchase. That said, it does exist. Research your local laws regarding personal backups and plug the relevant terms into a search engine.

Moving to SSD

Hi Doc, I have a 1TB SSD and two hard drives. The SSD is used for my OS and program files. Hard drive one is loaded with data and downloads that I want to save. I keep these separate for easy backup, and because I don't want to fill the SSD. My second mechanical disk serves as backup for the first. I run a program called Second Copy to perform saves when needed. I also back up to a portable USB-attached hard drive for long-term storage.

Does it make sense, as solid-state storage is fairly low-cost, to add a second SSD for big data files? I'm talking mostly 50MB files, with larger ones in the 4GB range. The purpose would be reading and writing big files faster, rather than waiting on a slower hard drive.

I don't think I have a slot for another M.2 PCIe SSD, but I'm pretty sure there is room in my case, along with a motherboard port and cable, to accommodate a SATA SSD. I want to be sure I'll notice enough of an improvement to make it worthwhile. Or is there an even better solution, such as RAID? **Doug Schafer**

THE DOCTOR RESPONDS:
The idea behind tiered storage is to balance performance, availability, and cost. Keeping a library of movies or documents on hard drives makes sense because mechanical disks cost less per gigabyte than solid-state storage. Moreover, you don't worry about transfer rates once those files are open.

That said, if you consistently find yourself waiting on large files to open or game levels to load, it makes sense to add another SSD. Even over SATA, near-instantaneous response means you aren't waiting on a hard drive's read heads to seek. The difference is absolutely palpable.

Threadripper Speed

Hi Doctor, I have a question about the memory to use with a Threadripper 2950X. According to AMD's product page, it supports a maximum data rate of 2,933MT/s. If I want to overclock, do I need modules capable of 3,000MT/s or higher? This is for a new video editing PC I'm building. **Marvin Malasky**

THE DOCTOR RESPONDS:
AMD's Ryzen Threadripper CPUs respond well to fast DDR4 memory. A 3,200 or even 3,466MT/s configuration should yield quantifiable gains in bandwidth-limited workloads. Overclocking the power-hungry 2950X requires more than just a capable quad-channel kit, though.

First, make sure your mobo is up to the task. A lot of the early Socket AM4-based platforms support second-gen Threadripper models at their stock settings, but struggle to deliver the power needed for aggressive tuning. An enthusiast-oriented PSU with a pair of native EPS connectors is mandatory, too.

Video editing tends to fully utilize host processing resources and the 180W 2950X is already a warm chip. Overclocking exacerbates its thermal output, so consider liquid cooling with a full-coverage block. You might also want to use AMD's Precision Boost Overdrive in the Ryzen Master software. Rather than overclocking manually, PBO takes the reins and increases clock rates as much as possible inside certain power, current, and temperature limits. When you're not using your PC, it lowers clock rates and voltages to minimize power consumption.

YouTube Buffering

Hi Doc, I like to watch videos on YouTube, but I always seem to get that buffering circle spinning on the screen. I pay for AT&T's 1Gb/s Fiber package. Any tips or suggestions? **Dennis Cossa**

THE DOCTOR RESPONDS:
There are many variables in between your high-end PC and YouTube's servers that might affect streaming performance, including your router, your ISP, and other content delivery networks hosting data.

Common suggestions include clearing the browser's cache, restarting your router, and blocking YouTube's CDNs either from Windows' built-in firewall or your router's. You can also check the health of your connection to YouTube: Open a video, right-click it, and select "Stats for nerds."

Google's own suggestions include restarting your browser, rebooting your PC, closing all other browser tabs, making sure you're using the latest version of your browser, and, of course, using its own Chrome browser.

GEAR OF THE YEAR

A lot has happened in the last year, with plenty of game-changing releases, but which bits of gear should you be lusting after? **BY THE MAX PC TEAM**

RAZER BLADE 15

$2,399

Proving gaming laptops don't have to be big, brash boys' toys, the Razer Blade 15 offers genuine gaming performance in a sleek, well-built design. Numerous build options are available, but we found the combo of GTX 1070 and Core i7-8750H strikes a great balance between value and performance.

Website: www.razer.com

Reviewed: Vol 23, No 10, Page 78

Since this time last year, we've had new processors, new graphics cards, improved SSDs, peripherals aplenty, and a wealth of nips and tucks to put the PC in as good a shape as it's ever been. However, not all the changes have been obviously for the better, with some releases being downright confusing in terms of the bigger picture. So, what hardware have we been most excited about over the past 12 months? Which releases stand out as being modern classics? Well, it's time to find out.

Before we dive into the various categories, though, it's worth noting that in the case of full systems and laptops, we are still expecting some major changes to filter through. We've yet to look at a machine that employs Intel's ninth-generation chips or AMD's new Zen+ CPUs, and the same goes for Nvidia's RTX graphics cards. So, it may be worth waiting a bit to see what system builders do with the latest technology before pulling the trigger on a big purchase.

Speaking of graphics cards, the jury is still very much out when it comes to the ray-tracing revolution. The hardware may be here, but until we get the games that actually use the technology, they're very much an unknown entity. It could well be that it's DLSS (Deep Learning Super-Sampling) that is the killer app for these graphics cards, but again, we don't know for sure just yet.

With that said, let's move on to look at the gear that is impressive right now. From kick-ass laptops to mice that have stood head and shoulders above their peers. What follows is the very best gear to be released in the past year. The pinnacle of PC hardware.

GIGABYTE AERO GI15X V8-BK4

Gigabyte's thin-and-light gaming-focused Aero delivers on the promise of Nvidia's Max-Q design philosophy. While it's marginally slower than Razer's offering, it's also at a more appealing price point. Cool running and packed with great tech, including a luscious 144Hz IPS screen, this is a great option for any would-be gamer.

Website: www.gigabyte.com
Reviewed: Vol 23, No 11, Page 76

$2,199

DIGITAL STORM BOLT X

Squeezing a ton of sweet gear into such a svelte, sumptuous case, Digital Storm's Bolt X proves that money well spent will last you years. The combo of Core i7-8700K and GeForce GTX 1080 Ti still stands up, even against newer hardware releases, providing knockout performance in the latest games, backed up by a brilliant warranty.

Website: www.digitalstorm.com

Reviewed: Vol 23, No 3, Page 78

$3,489

FALCON NORTHWEST TIKI

At release, the Tiki was the pinnacle of boutique PC building, with a price to match. Falcon Northwest has updated it with the very latest hardware, including RTX 2080 Ti GPUs and the latest ninth-gen and Threadripper processors. Spec it out with the latest gear, and you can hit ridiculous performance figures for considerably less than this.

Website: www.falcon-nw.com

Reviewed: Vol 23, No 4, Page 74

$9,740

PHANTEKS ECLIPSE P300

Who says quality cases need to cost a premium? Not us, and clearly not Phanteks. The Eclipse P300 manages to encompass a ton of high-end features into its affordable design, including a tempered glass side panel, support for numerous AIO coolers, and storage aplenty. The design is refreshingly understated, and overall it's a beautiful case to build in.

Website: www.phanteks.com

Reviewed: Vol 23, No 1, Page 88

$60

CORSAIR OBSIDIAN 500D

In a world of samey boxes, the Obsidian 500D is a breath of fresh air. With its subtle curves and glass side panels, it's ideal for anyone who wants to build a system beyond the norm. With great cooling support, clean internals, and room for crazy storage, this is the standout case of the last year. That price equates to incredible value for money, too.

Website: www.corsair.com

Reviewed: Vol 23, No 12, Page 87

$140

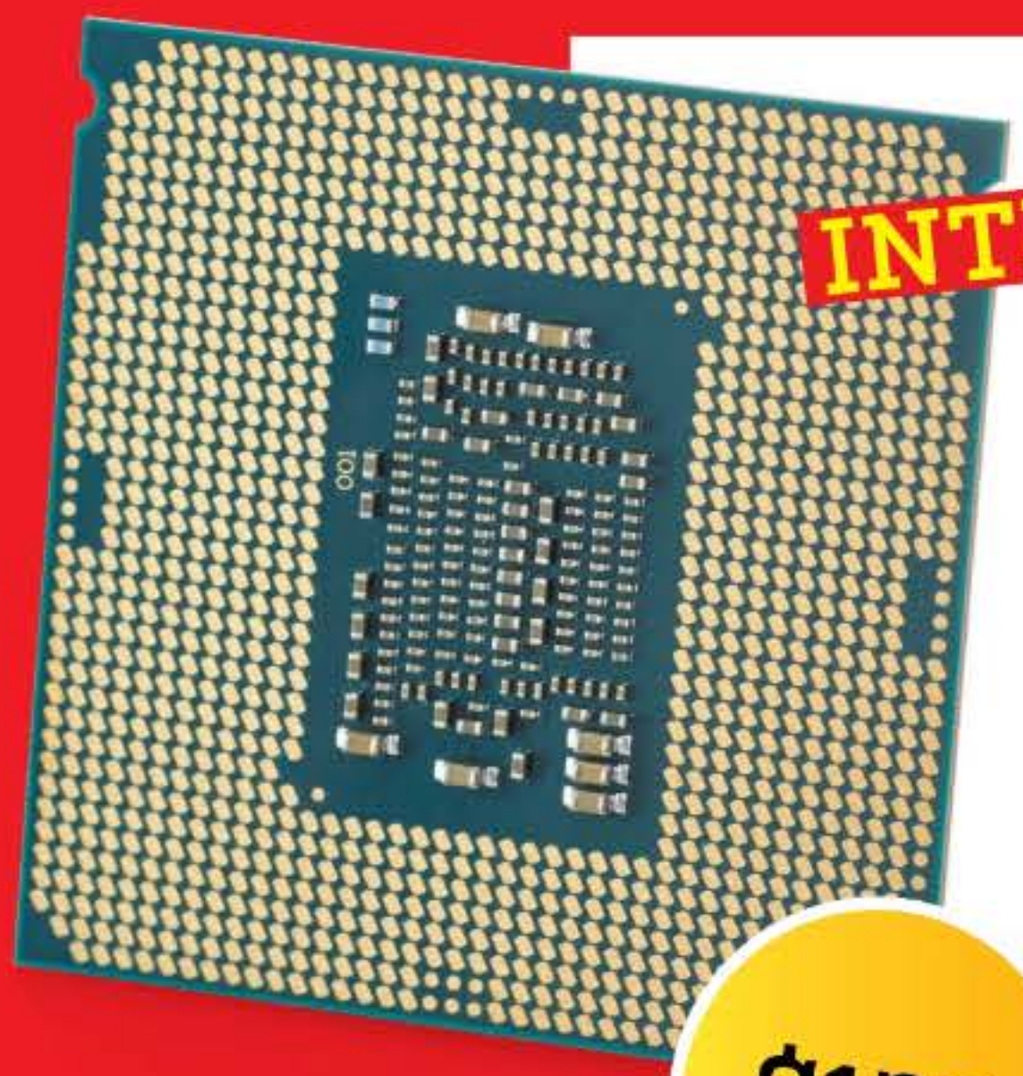
NZXT H400I

MicroATX hadn't seen much love until the NZXT H400i came along. With its quality materials, beautiful finish, and solid design, this is a case worth moving to microATX for. Despite its diminutive frame, it offers great cooling options, and is surprisingly spacious to work in. It's $20 less than at launch, too.

Website: www.nzxt.com

Reviewed: Vol 23, No 4, Page 89

$130



INTEL CORE I3-8100

Intel's eighth-gen Core i3 saw a healthy upgrade to a quad-core, quad-thread configuration, which means it's effectively a Core i5 from a few generations previous. The single-core performance gives it the edge over AMD's comparable offerings, and the full-fat PCIe lanes mean it plays nicely with graphics cards, too. A great budget option.

Website: www.intel.com

Reviewed: Vol 23, No 5, Page 79

$130

AMD RYZEN 7 2700X

Zen+ may be more of an improvement to the production process, but it still resulted in one of the most important processors of the year. The eight-core, 16-thread Ryzen 7 2700X might only be 10 percent better than its predecessor, but it's still a lot of chip for just over $300. If you want performance and great value, look no further.

Website: www.amd.com

Reviewed: Vol 23, No 7, Page 74

$310

INTEL CORE I9-9900K

You can thank Ryzen for the fact that Intel has had to release an eight-core, 16-thread "mainstream" CPU, but that doesn't detract from the fact that this is a phenomenal chunk of silicon. Overclockable to 5GHz, or Turboing up to that at stock, it offers class-leading single-core performance, with plenty of cores for multicore action, too. Expensive, but then the best tends to be.

Website: www.intel.com

Reviewed: Vol 23, No 13, Page 78

$530

AMD THREADRIPPER 2950X

Second-generation Threadripper is all about big numbers. With a whopping 16 cores and 32 threads, 32MB of L3 cache, 64 PCIe lanes to call its own, and support for up to 128GB of quad-channel DDR4, this is the kind of chip that high-end dreams are made of. It's unlocked for modest overclocking action as well.

Website: www.amd.com

Reviewed: Vol 23, No 12, Page 74

$899

MSI X470 GAMING M7 AC

It's fair to say that the first-gen Ryzen motherboards had teething problems, but the X470 offerings upped their game significantly. This X470 board from MSI is a prime example, with its strong feature set, impressive performance, and decent overclocking headroom. It's one of the pricier Ryzen options, for sure, but it's worth it.

Website: www.msi.com

Reviewed: Vol 23, No 7, Page 78

$230

GIGABYTE Z370 AORUS ULTRA GAMING 2.0

Intel's best Coffee Lake CPUs tend to be found at the budget end of the spectrum, which means that there's a need for great value compatible motherboards. Such as this fine specimen from Gigabyte, which offers everything you need in a decent-looking design, at a price that makes sense. A solid all-arounder, in other words.

Website: www.gigabyte.com

Reviewed: Vol 23, No 8, Page 80

$150

GIGABYTE X470 AORUS GAMING 7 WI-FI

Gigabyte's X470 flagship manages to marry form with function to great effect, to produce a solution that not only looks good, but does a good job of keeping the hotter portions of the board cool, too. It boasts a genuinely useful feature set, offers great performance across our tests, and still manages to represent great value for money.

Website: www.gigabyte.com
Reviewed: Vol 23, No 9, Page 76

$230

ASUS ROG MAXIMUS X FORMULA

$350

Dripping with connectivity, tasty armor plating, and even offering support for liquid cooling, this is a board that's a notable cut above the rest. The standout feature for many is the OLED display that can be found at its center, which can display voltages, clock speeds, and more. Impressive performance and overclocking-friendly, this is a joy to build a PC around.

Website: www.asus.com
Reviewed: Vol 23, No 10, Page 82

CRUCIAL MX500 500GB

$100

There's no denying that PCI Express SSDs are faster, but such drives are notably more expensive. If you want a decent amount of storage, there's still a lot to like about SATA drives, and this is the benchmark by which others are judged. Decent performance, incredible bang for your buck, and a five-year warranty—what's not to like?

Website: www.crucial.com
Reviewed: Vol 23, No 4, Page 79

SAMSUNG 970 EVO 1TB

One terabyte of speedy PCI Express storage used to cost silly money, but with the 970 Evo, this can now be had for under $300. Color us impressed. Pretty much butting up against the limitations of the underlying technology, you probably won't see much faster than this in the mainstream anytime soon, making this the only real choice for mainstream builds.

Website: www.samsung.com
Reviewed: Vol 23, No 8, Page 85

$278

SAMSUNG 970 PRO 512GB

The 970 Evo is the drive of choice for mainstream builds, but if you need the best performance around for more serious work (or more serious gaming), the Pro is the logical option. Simply faster across the board—whether you're talking straight throughput or IOPs—this is the go-to drive for enthusiasts. More expensive, for sure, but easy to justify.

Website: www.samsung.com
Reviewed: Vol 23, No 9, Page 82

$198

CORSAIR HYDRO H150I PRO RGB

You want your all-in-one water cooler to be easy to install, quiet, and able to keep your CPU chilled as you push for that perfect overclock. The Hydro H150i Pro checks all these boxes, and has served us admirably across a range of chips ever since it hit our test labs. The precise fan control, RGB lighting, and zero-rpm mode all make for a knockout cooler.

Website: www.corsair.com

Reviewed: Vol 23, No 5, Page 88

$170

MSI GEFORCE GTX 1080 TI GAMING X TRIO

It's telling that this is the only graphics card we've looked at in the last year that has scored high enough to be included here. The 1080 Ti is still a knockout GPU 12 months on. Indeed, until we see some ray-tracing and DLSS games that justify the price of the RTX cards, we don't see that changing.

Website: www.msi.com

Reviewed: Vol 23, No 1, Page 82

$800

SEAGATE IRONWOLF 12TB

SSDs have come a long way in terms of value for money, but they still can't compete with decent spinning platter drives. Weighing in at an incredible 12TB, this is a breathtaking option if you're after a serious chunk of storage. The performance is relatively impressive as well, with sequentials at 270MB/s.

Website: www.seagate.com

Reviewed: Vol 23, No 5, Page 87

$399

$250

1MORE 1MEJH0006

What's the single most important thing for a headset to get right? The sound it produces, of course. And it's here that this set of cans excels. The beautifully tuned 40mm graphene dynamic drivers, ceramic tweeter, and bass reflector produce a simply incredible soundstage. The sort that makes you enjoy audio in a whole different way. Yes, it's expensive, but so worth it.

Website: https://usa.1more.com
Reviewed: Vol 23, No 8, Page 86

$80

CORSAIR HS70 SE WIRELESS

If your budget won't extend to the likes of the 1More, and/or you're looking for a bit more freedom when enjoying your audio, this wireless offering from Corsair is well worth a look. Ignore the claims of 7.1 surround sound, and just enjoy a perfectly balanced, aesthetically gorgeous headset. The microphone is really good as well.

Website: www.corsair.com
Reviewed: Vol 23, No 9, Page 89

ROCCAT VULCAN 120

For a company better known for its budget-oriented peripherals, Roccat's Vulcan 120 stands out for its high-end brilliance. The star is the company's own Titan Tactile switches, which are smooth and responsive, with a super-low actuation point. It's a great clean design as well, with RGB LEDs aplenty.

Website: www.roccat.org
Reviewed: Vol 23, No 10, Page 88

$160

$81

ROCCAT KONE AIMO

It would be easy to dismiss the Kone AIMO as a gimmicky mouse, because its main selling point appears to be the fact that it's covered in lights, but that would mean missing out on what is ultimately a brilliantly versatile mouse. The 12,000 dpi sensor, a Pixart 3361, which Roccat has tinkered with, gives plenty of control, while the overall design is well proportioned for a wide range of hands.

Website: www.roccat.org

Reviewed: Vol 23, No 7, Page 89

$72

STEELSERIES RIVAL 600

Balance is the name of the game when it comes to this excellent mouse, with the Rival 600 offering a range of weighting options, depending on how you install the eight 4g weights. Fully loaded, it's a hefty beast; while empty, it glides effortlessly across your surface of choice. The decision is very much yours. Get it right, and it can feel amazing.

Website: www.steelseries.com

Reviewed: Vol 23, No 6, Page 87

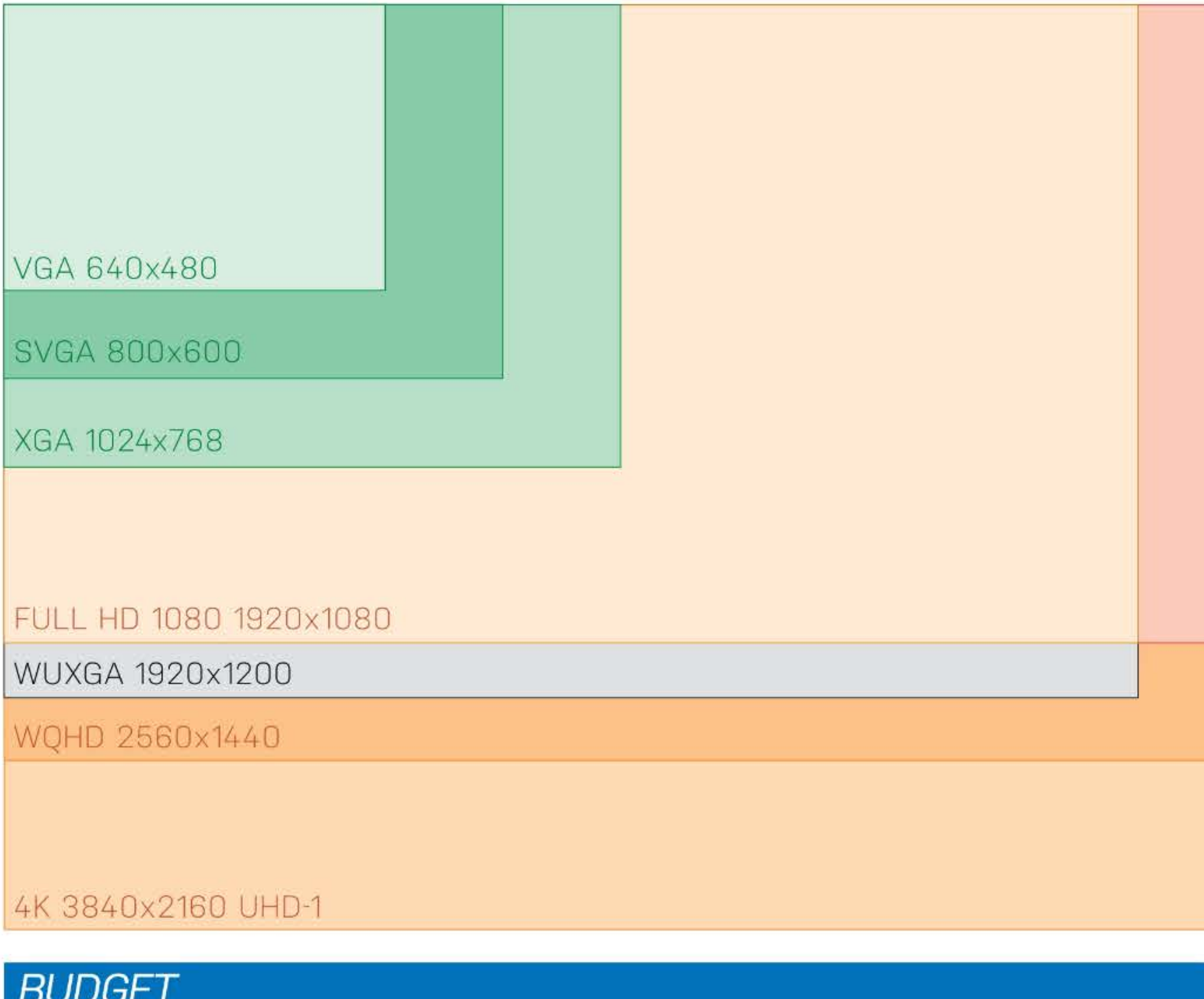
WOOTING ONE

There are lots of elements that set this keyboard apart from its peers, but its the analog key switches that grab the headlines. Just let that sink in for a minute: an analog keyboard. You can set it up to respond differently depending on how far down you push each key, or just revel in its wonderful typing experience. Brilliant, versatile, and, yes, expensive. But it could just be the best keyboard we've ever used.

Website: https://na.wooting.store

Reviewed: Vol 23, No 13, Page 86

$140



BUDGET

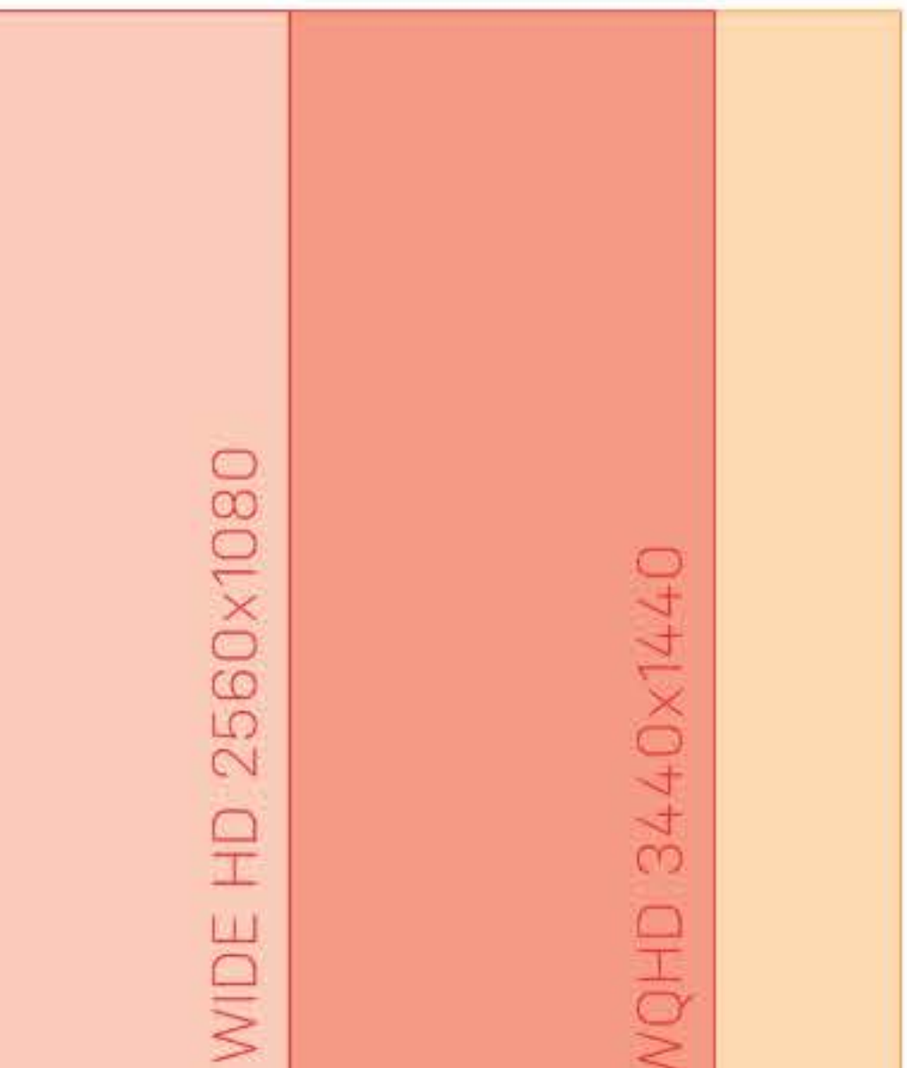
DELL SE2717HR

Maximizing your bang for buck at the budget end of the market is very much a moving target. As we go to press, for instance, Newegg is listing this rather desirable Dell SE2717HR for just $135. It's one hell of a lot of PC monitor for the money.

Certainly, it checks all our boxes at this end of the market. For starters, it's made by a recognizable and big brand. That doesn't guarantee an absence of major horrors—even the big boys get it wrong—but it reduces the chances of buying a total dud. Typically, it's also easier to find end user reports concerning monitors from the larger manufacturers. There are simply more of them out there.

Whatever, this is a 27-inch model with an IPS panel and static contrast of 1,000:1. So, you're guaranteed good viewing angles, plus decent contrast and colors. The most obvious shortcoming is the mere 1080p native resolution. That translates into 1920x1080 pixels. On a 27-inch LCD panel, you are therefore looking at just 82 pixels per inch. Not terribly impressive. But then it's available right now for just $135. It's not perfect, but it's one heck of a lot of PC monitor for the money.

A big-brand 27-inch IPS panel for 135 bucks is hard to beat.



THE BEST SCREENS FOR EVERY BUDGET

You now get more monitor for your money *By Jeremy Laird*

A DECENT SCREEN has traditionally been one of the best, if not actually the very best, long-term investments you can make for your PC. In the past, that's reflected the fact that screen technology has ambled along at a leisurely pace. Back in 2006, for instance, Dell rolled out its 30-inch 3007WFP. It wasn't cheap at about a thousand bucks, but it took the better part of a decade for monitors to appear that made it truly redundant. Divide that $1,000 upfront investment by seven or eight years of use, and the annual price of having a fantastic display doesn't look bad.

More recently, the monitor market has gone more or less mental. Over the last four or five years, the innovations have come thick and fast. Most obviously, the range of form factors has exploded. It's amusing to consider how exotic the first 16:10 and 16:9 aspect widescreen monitors seemed now that superwide 21:9 monitors are commonplace, and

MID-RANGE

LG 34UB88-P

If there's a controversial pick among our list, it's probably this, the LG 34UB88-P. It's a superwide 21:9 aspect monitor, and that's the problem. Not everyone jives with superwide. Moreover, at this money, you can also have your pick of 4K UHD panels up to 32 inches in size.

In truth, 4K and 16:9 would be our choice, too. But that's our all-around winner. So the LG represents something of an alternative mid-range choice. First up, there's that 34-inch IPS panel. It's a beauty, with 10-bit color (strictly 8-bit native, plus FRC) and 3440x1440 pixels. In extremis, that vertical pixel count could be constraining. But there's no question that this makes a great display for viewing multiple documents and web pages side by side.

The 21:9 aspect is also a perfect fit for feature films from the major movie studios, which fill the screen from edge to edge, and look fantastic. If you like a little casual gaming, you'll probably love the expansive view it gives into virtual worlds, too. The fact that the 34UB88-P also sports Thunderbolt and USB-C for slick connectivity, and is available on special at Newegg for $448 as we go to press, just sweetens the deal.

USB-C plus superwide visuals make this a sweet deal.

insane 32:9 screens can be had for about the same price as that venerable Dell.

Size has been on the up, too. Those 32:9 screens measure 49 inches across, while 27-inch monitors can be had for as little as $100. Then there's resolution. Screens delivering the full UHD experience—3840x2160 pixels—have recently slipped under the $200 barrier, while all kinds of crazy intermediate resolutions for superwide panels are available, and more conventional pixel grids, such as 1080p and 1440p, can be had seriously cheap.

If that's sounds good, it's just the beginning. Along with larger sizes, more pixels, and funky aspect ratios, you can now have your monitor with a curved panel. Both the appeal and utility of curved screens are arguably subjective. For some, they add to the immersion in games and movies, and make really large panels more ergonomic for desktop use. For others, curved screens just look silly.

Screens with amped-up refresh rates and adaptive sync technology are also now widely available. Both features are typically pitched as gaming-centric. That's certainly true when it comes to adaptive synching, such as Nvidia's G-Sync and the FreeSync alternative from AMD, which is increasing becoming the industry standard. It's great for smoothing out gaming performance, but has limited benefits beyond that. However, higher refresh rates that involve an increase from the standard 60Hz to anything from 120Hz up to 240Hz offer a much broader utility. Whether it's bumping apps around the desktop or scrolling documents and webpages, higher refresh rates make a PC feel slicker and more responsive.

That said, increased refresh rates put some serious load on your graphics subsystem; you need a video card capable of supporting the higher refresh rates. Increasing the refresh of a display from 60Hz to 120Hz doubles the bandwidth required from your graphics output. Consider that a 4K panel has four times the resolution of a 1080p panel, and it's easy to see how driving 3840x2160 pixels at 120Hz makes huge bandwidth demands; 4K running 120Hz means 16.5 million pixels sent to the display every second. Right now, only the DisplayPort 1.4 standard can achieve that, although HDMI 2.1 will add further support soon. Likewise, remember that, in gaming terms, to make the most of a high-refresh monitor, you need a graphics card capable of cranking out frames at a sufficiently fast rate. There's little point in paying more for a high-refresh monitor for gaming if you have to cut corners on your choice of GPU.

Another technology that's set to have a wide impact, but has so far proved problematic on the PC, is HDR (High Dynamic Range) rendering. In simple terms, HDR means both more brightness and darkness from a given display, thus a greater range of luminosity. The practical

Thirty-two inches and 4K is currently the sweet spot for affordable productivity.

TURBO

LG 34WK95U

Oddly, this is currently the trickiest category of all. That's because it's simply not possible to combine all the very best available technologies in any single screen. If you want 4K and high refresh, for instance, you can only have it on a 27-inch gaming panel.

We're also tempted by Dell's 8K beast, the UP3218K. It's very, very difficult to turn down 7680x4320 pixels. The problem is that's all the monitor has to offer; it's a one-trick pony, even if that trick is pretty stellar. It's also arguably a bit of a kludge, what with its requirement for dual DP cables for 8K at 60Hz.

Instead, we'll vote for LG's hot new 5K2K monitor, the 34WK95U. It's a 34-inch model, but packs 5120x2160 pixels, so it neatly defenestrates our main reservation with its mid-range sibling, the LG 34UB88-P, namely its lack of vertical resolution.

What's more, it's packed with awesome features. There's proper HDR support in the form of VESA DisplayHDR 600 certification, plus Nano IPS panel tech, so the visuals promise to be simply sizzling. Rounding the package out nicely is Thunderbolt 3 and USB-C connectivity.

LG's hot new 5K2K monitor is our premium panel pick.

implementation is more complicated. HDR standards applied to displays also widen the color gamut available. In theory, the result should be far more vibrant visuals. In practice, support for HDR from the Windows platform has been patchy.

The latest builds of Windows 10 do natively support HDR content. However, enabling that support currently has undesirable knock-on effects on SDR (Standard Dynamic Range) content, which includes the desktop. Long story short, HDR is not yet a seamless technology on the PC with no downsides. It still suffers from what we generously call some early adopter niggles. As it happens, HDR also makes more demands in terms of bandwidth from display interfaces. Combine HDR with high resolutions and refresh rates, and you have a bandwidth storm. Worth bearing in mind when considering your overall setup, particularly your choice of graphics card to complement the display.

QUANTUM SOLACE

There are further detailed advances, too, such as quantum dot technology, which improves color saturation via tiny flecks of photo-emissive material in the backlight, which rely on the quantum properties of electrons as they drop through energy levels when orbiting an atomic nucleus. As we said, the monitor market is innovation-happy right now.

Despite that, there's an argument for saying the modern LCD monitor remains remarkably flawed. Yes, LCD tech has improved beyond recognition compared to the earliest passive matrix panels, but LCD remains a fundamentally bad idea for a full-color display technology. That's chiefly because it's transmissive rather than emissive. It requires a backlight, and in turn the ability to block and mediate that backlight, which LCD will never be able to do with absolute precision or complete totality. In other words, an LCD monitor with perfect contrast and viewing angles is a huge and perhaps insoluble problem.

The obvious alternative is OLED. That has clear advantages, including fully switchable pixels, each of which are their own light source, and essentially perfect viewing angles. OLED technology is already common in smartphones and ramping up in HDTVs, but it's taking its sweet time to transition to PC monitors, more's the pity. The other obvious shortcoming with today's displays involves native panel resolution. There has recently been a trickle-down effect courtesy of UHD TVs that has enabled a wide range of affordable PC monitors with 3840x2160 UHD or 4K pixel grids, which is thoroughly welcome. And yet it's also

GAMING

ASUS ROG SWIFT PG35VQ

We were tempted to pick Samsung's 49-inch C49HG90. With its insane 32:9 aspect ratio plus 144Hz refresh and HDR support, it's quite a package. But with just 1080 vertical pixels and patchy support for legacy games, its appeal is just a little too narrow. It's awesome, but the best all-around gaming monitor? That's a real stretch.

Behold, therefore, the Asus ROG Swift PG35VQ. This bad boy has almost everything. The panel is a 35-inch 3440x1440 affair, which means a perfect balance between visual detail and high frame rates. The latter is highly relevant given this screen is capable of no less than 200Hz.

Then there's proper HDR10 support with 512-zone local dimming, and Nvidia G-Sync for the last word in rendering smoothness. Oh, and there's quantum dot enhancement to the backlight for good measure. It's been a long time coming, having been announced in 2017, but it should be available at retail by the time you read this. It won't be cheap, though, at around $2,000. For the record, Acer's Predator X35 is based on the same HDR panel from AU Optronics, and offers essentially the same specifications.

HDR with 512-zone local dimming at 200Hz? You bet!

notable that truly high-density desktop PC displays still don't exist. At least, not for a remotely affordable price they don't.

Again, the uncomfortable comparison here is smartphones. A basic smartphone with a display panel packed with at least 300 pixels per inch can be had for relative pennies. Ditto tablets with high-density screens. As for high-end smartphones, their displays commonly cram in over 500 pixels per inch. But PC monitors? UHD or 4K sounds impressive, but stretched out over a 40-inch panel, those 3840x2160 dots make for just 110 pixels per inch. Even on a 27-inch monitor, you're only looking at a little over 150 pixels per inch from a 4K grid. The closest thing we've seen to a true high-density or high-DPI PC monitor is Dell's 32-inch 8K monitor, the UP3218K, which works out at 275 pixels per inch—or roughly comparable to an entry-level smartphone.

Granted, it's true that ergonomics have a part to play here. Smartphone screen viewing distances are typically shorter than those of desktop PC monitors, but not enough to make up for the huge gap in pixel density. Consequently, something is surely amiss when the fonts on a cheap smartphone are infinitely crisper and cleaner than a megabucks PC monitor.

If that's how far screen tech has come, and a few thoughts on what it hasn't yet achieved, how do you choose from the huge range of monitors on the market today? What, in other words, really matters? For starters, a quality panel and some decent electronics still go an awfully long way. By way of example, it's all very well having 144Hz refresh support, but if the monitor has a low-resolution TN panel, no amount of fast refresh is going to make it a great display for desktop productivity.

So, the first thing to do is understand your panel types. TN tech remains the fastest, so has plenty going for it in games, but is weak by just about all other metrics. For everything else, IPS or VA is your best bet. The former majors on color accuracy, offers the best viewing angles, decent response, and reasonable contrast. VA is the undeniable daddy when it comes to color saturation and contrast, but it can't quite match IPS for accuracy, and is the slowest option of all for pixel response.

THREE BECOME ONE

Admittedly, as LCD technology in general has progressed, the three major panel types have converged, so there are no hard and fast rules. But gamers generally prefer TN or IPS (though some of the very latest VA panels offer gaming-centric capabilities), content pros want IPS, and everyone else should go for IPS or VA, the latter being a good choice for movie buffs.

Once you've picked a panel type, you need to decide on form factor, resolution, and refresh. Gamers should remember that higher resolutions and refresh rates make huge demands on the graphics subsystem. Right now, 1440p or 2560x1440 pixels still looks like a very good compromise between detail and playability. Make that 3440x1440 if you prefer superwide aspect ratios. For productivity and general use, you might think going bigger is always better, but if you don't up the resolution in parallel with the panel's proportions, the result will be big, fat ugly pixels, and no additional desktop elbow room. Meanwhile, really high resolutions on smaller displays can

ALL-AROUND

AOC U3277PWQU

A quality 32-inch VA panel with full 4K or UHD resolution for just $330? Just 18 months ago, that would have seemed impossible. But a screen that fits that description is sitting next to the *Maximum PC* test rig as we write.

It's the AOC U3277PWQU, and just one of many monitors that make up the broader 32-inch UHD or 3840x2160 pixel segment. It's a category that has exploded over the last 12 months, and for good reason. The UHD resolution provides oodles of desktop space. Combining that with a 32-inch diagonal is also a good compromise. Arguably, both the web and Windows aren't quite ready for true high DPI displays, and this monitor class works well at 125 percent scaling. At the same time, the size and resolution work out at 137 pixels per inch, and thus it's usefully sharper than, say, a 27-inch 1440p monitor.

This AOC model isn't perfect—the color balance is a little over-saturated—but for the money, it's magnificent, and if you want to spend a bit more, similar screens with more accurate colors and even HDR capability can be had for as little as $500. It really is a great time to buy a screen.

The AOC U3277PWQU: A magnificent monitor for the money.

Quantum dot is just one of many new techs enhancing screen quality.

High-density displays are the norm for smartphones, but not yet for PC monitors.

Adaptive sync technologies, such as Nvidia's G-Sync, make for much smoother gaming.

make for increased pixel density, but run into scaling problems, both with the Windows interface and the web. Our general advice is don't go smaller than 27 inches with a 4K monitor, unless you know exactly what you are doing, and likewise don't go bigger than 27 inches with 1440p.

As for HDR support, for now it's a niche pursuit on the PC. It's nice to have, rather than a must-have for gaming. Ditto for movies. For everything else, the technology needs to mature a little further. That said, support for HDR generally indicates a screen with greater basic fidelity, so bought on those terms, rather than necessarily to watch HDR content, such screens can make sense.

On a related note, it's worth understanding the broader color depth categories. Avoid monitors that are natively 6-bit per channel, even if they support 8-bit color with dithering, sometimes referred to as FRC; 6-bit indicates a very low spec panel. Color pros may want to consider panels with 10-bit support, but if you're not fully familiar with these terms, you don't need anything beyond 8-bit per channel, so long as the panel supports that natively, as opposed to via dithering. It's a similar story for color space support. If you're a content pro, and you know your target gamut, you won't need our help. For everyone else, paying a premium for extended color space support probably isn't worth it.

Our final factor is the display interface. The best bet is to think end-to-end. You need support from both the display and the video card. If your graphics card is old enough to limit your screen options, think about changing GPUs. Remember, if you don't game, you won't need a megabucks graphics card. You just need something recent with decent output options. For maximum future-proofing, go for a card with both DisplayPort 1.4 and USB-C. DisplayPort 1.4 offers the maximum available bandwidth today, including 4K at 120Hz, and supports the widest range of monitors. USB-C is very appealing, too. It effectively outputs DisplayPort in an alternate mode, but can also transmit data and power. So it's great for minimizing cable clutter, and definitely the interface of choice if you're driving your screen with a USB-C capable laptop PC.

And that pretty much covers it. For more specific advice, check out our segmented categories, but as a general rule, we advise maxing out your display investment. It will last you for years, and you'll be glad you spent the extra money every time you use your PC.

FUTURE TECH

MAXIMUM PC MEGAMONITOR

Despite all the innovation on offer in the current monitor market, it's notable that there's no one monitor that combines all the best current features in a single screen. If you want a large format, very high resolution screen with equally lofty refresh rates, you are out of luck. So what would be the makings of our ideal monitor?

For starters, it would be even higher resolution than 4K. We think the PC should have lovely, crisp fonts, just like a smartphone does. In a large format display, that requires at least 8K. We also like the 21:9 aspect ratio. So, let's make that a 34-inch display, clocking in at 7680x3290 pixels. Nice.

Then it will need to be at least 120Hz, and offer true HDR support. The latter could be enabled via an LCD panel with high-resolution local dimming, but an OLED panel would be even better. Oh, and we would like to be able to run the whole thing via USB-C. As it happens, the current DisplayPort 1.4 interface would actually support all that, courtesy of display stream compression. So, our dream monitor isn't completely pie in the sky. It wouldn't be cheap—but it would be worth every single dollar.

We await a truly worthy successor to the Dell 3007WFP.

SPECIFICATIONS DEMYSTIFIED

Panel Size

This is the visible diagonal of the screen, measured in inches. Screens are built to different aspect ratios, so this can be a little misleading at times, especially when you're looking at some of the superwide panels. This specification needs to be considered in tandem with the resolution to make real sense of what's being offered. For a curved screen, we quote the monitor curvature, with the number before the "R" being the radius of the curve in millimeters.

Native Resolution

The number of horizontal and vertical pixels present on the screen.

Pixel Density

Take the native resolution and divide by the physical panel size to get the pixel density, measured in pixels per inch (ppi)—or dots per inch (dpi). Modern screens have crazy pixel densities, although for most desktop panels, you're looking at something between 100 and 160 ppi. Generally speaking, the higher the better, although you can get to a stage where it's difficult to see what you're actually doing—the Dell P2415Q was a 24-inch panel with a native 4K resolution (185 ppi) that was just a bit too small to be useful.

Panel Type

There are three main panel types in modern screens: TN (twisted nematic), IPS (in-plane switching), and VA (vertical alignment). There are many variations on these that try to offset some of the problems associated with them, such as MVA (multi-domain vertical alignment), which offers improved response times over VA, but the base concepts are the same.

Maximum Refresh

The refresh rate is the number of times the display updates per second, measured in hertz (Hz). Low refresh rates equate to flickering, while the norm for LCDs has been 60Hz for generations. There's been a push for higher refresh rates, as that produces a smoother experience; 100Hz, 120Hz, and 144Hz are now fairly commonplace.

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Response Time

The amount of time it takes a pixel to change, measured in milliseconds (ms). This tends to be from one gray state to another gray, referred to as gray-to-gray. There is no industry standard when it comes to the measurement of response times, which means that you can often take these figures with a pinch of salt. Slower response times create blurring, so lower numbers are better.

Contrast

The ratio between the lightest color (white) displayable by the screen compared to the darkest color (black). Modern displays offer dynamic contrast ratios, which means that there is more granularity in particularly bright or dark scenes. Again, there is no industry standard for measuring this.

Display Inputs

For your display to be useful, you need to be able to connect it to your PC. There are numerous connection standards related to doing this, plenty of which are now defunct, but generally you're looking at DisplayPort, HDMI, USB-C, and mini DisplayPort for modern screens.

Connectivity

In many situations, the monitor can be the main focus for your computing use, so having USB ports on the screen makes sense. Indeed, as we move over to more displays supporting USB-C inputs, we are starting to see screens with integrated hubs offering RJ45 networking ports as well—great for plugging your laptop into.

VESA Mount

Most display stands offer height and tilt adjustment, but if you want to take full control of your screen, it's worth keeping an eye out for VESA mounting. The VESA Mounting Interface Standard (MIS) supports a range of mounting options, depending on the size and weight of the screen. Most monitors adhere to the 100 x 100mm standard.

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TECH PORN

1 LIQUID COOLING
This isn't the first EK heatsink we've seen on a Formula, but that doesn't make it any less impressive. Liquid-cooling your VRMs means you can ramp up the voltage, and get a more balanced current and a cleaner overclock. The G1/4 threads are compatible with all liquid-cooled fittings, too.

Asus Maximus XI Formula

THERE'S NO MOTHERBOARD series in existence today that commands as much respect as Asus's Maximus Formula lineup. Tech Porn has often played host to these heart-stoppers, and with good reason. If you're looking for innovative feature sets, brand-new design directions, and a motherboard that puts pure performance above absolutely everything else on this mainstream Intel platform, the Formula is the one for you.

It has historically been a liquid-cooled masterpiece. A juggernaut of a board fitted with PCB-shielding armor, a rigorously designed backplate, and enough connectivity to saturate any Intel platform it found itself on. Time and time again, the Formula continues to demolish the competition. Fast-forward to Sky Lake, and we also finally see the introduction of its non water-cooled brother, too, the Apex, for those not so bothered about the EK-designed VRM copper heatsink.

The Maximus XI Formula doesn't deviate from this mindset; its clean lines, neutral color palette, and two-way mirrored finish subtly enhance the performance-driving 10-phase power design encapsulating the socket. From performance to cooling, to expandability, and pure grunty looks, the Formula has it all. **-ZAK STOREY**

2 OLED MASTERY

This little slither of silver here is actually an active and fairly advanced OLED display. Showing everything from BIOS debug codes to in-depth animations, logos, and more, it's a fantastic way of showing off your system specs.

3 M.2 SSDs

The Formula supports two M.2s, hidden just under the second PCIe slot. The aluminum armor here acts as a heatsink, with two thermal pads located underneath, supporting whatever PCIe SSDs you throw in it, and reducing prolonged load thermal throttling.

CLONE RANGER

Sometimes, there's nothing more useful than a dumb copy of your drive, but what's the best way to achieve that? We'll show you... *By Neil Mohr*

Back in the July 2018 issue, we looked at some easy ways to keep your precious data safely backed up. Part of the rationale of any backup strategy is not to bother with any data that can be easily downloaded again, which is why backups usually ignore boot drives these days. User folders store configuration files, and the general OS files are restored when you reinstall, right?

As true as that is, there's still a couple of arguments for running clone operations; one of the most common is to migrate your boot media, transferring it from an old slow HDD, or perhaps shifting from an outdated SSD to a more modern one. The other argument is backup—while it's true you can reinstall Windows from scratch, we all know how long that can take, and don't get us started on updates. So, if a clone can be created easily and quickly, it can offer a simple way to deal with future problems.

We're going to look at two options, one that Microsoft offers and the other an open-source solution. The first is the tried and trusted Windows System Image. It's convenient, because it can run live as you use your system, and it ties in to the default Windows Recovery system. We're also going to look at the off-putting but incredibly flexible Clonezilla, created back when everything was called <project>zilla.

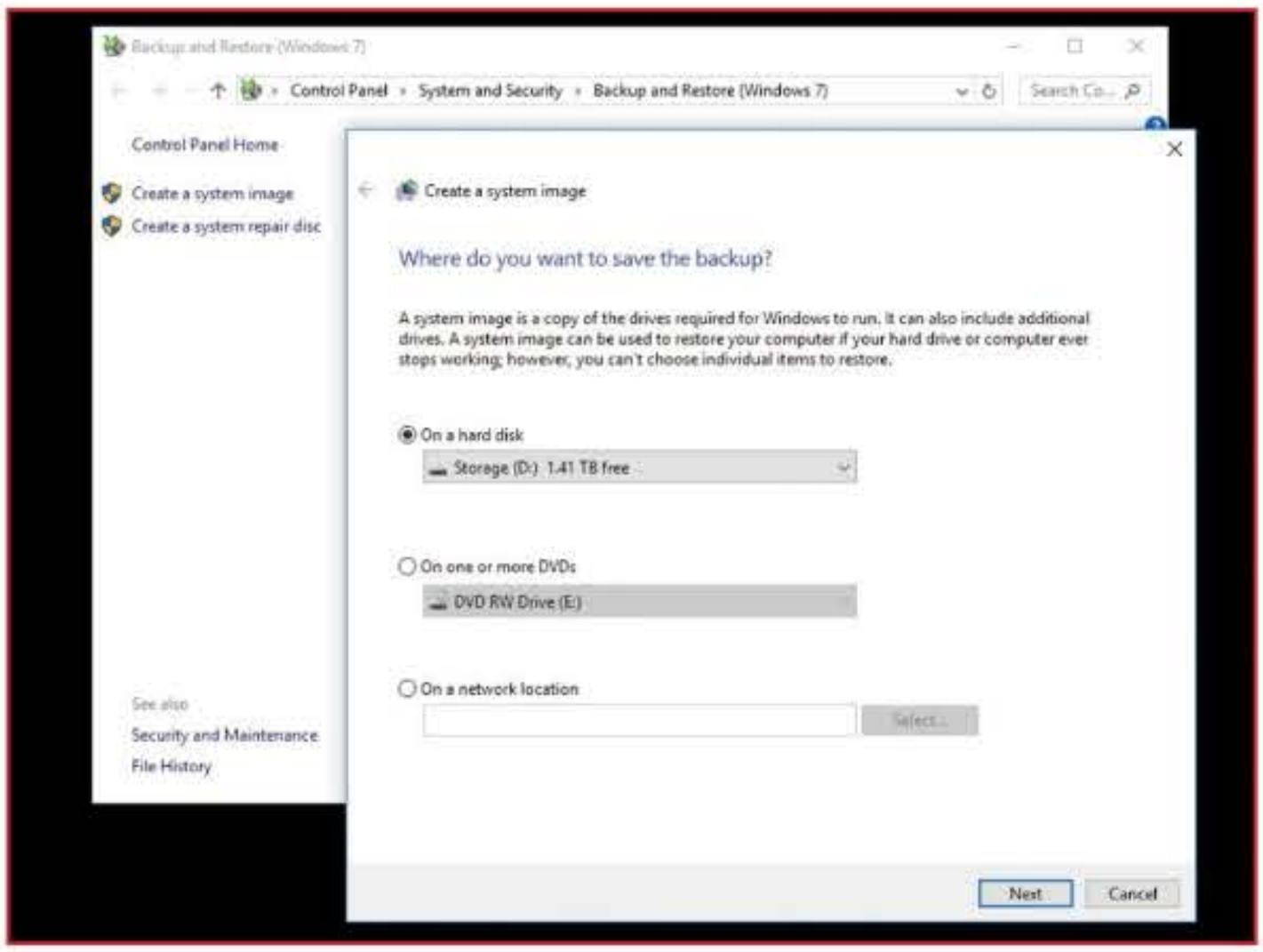
Cloning or imaging? We really should get our parlance sorted before we continue. When most people think of imaging a drive, it's the process of copying an entire drive or partition to an image file stored elsewhere. In terms of drive cloning, people tend to think of "live imaging" of one drive or partition to another drive or partition on the fly.

Essentially, both processes are the same, it's just the destination that's different. Once a drive image is written to another drive, you've accomplished the same cloned state, just with an extra write step. To keep things simple, we'll call it all drive or partition imaging; if we're doing it disk-to-disk or disk-to-file, it's hardly going out of our way to say so.

Typically with backups, an incremental option should be available. This is a drive image that only stores the bytes that have changed, so it's quicker. Sounds useful, huh? Annoyingly, neither the Microsoft option nor the open-source tool support this, though it's not out of the question.

To be fair on Microsoft, imaging isn't a well-regarded way of backing up data these days, especially if you can't use an incremental system. It's time-consuming, and even considered pointless. If you have a boot drive larger than 240GB, you might want to consider another approach or repartitioning, so your user data is stored separately from Windows.

Unix-based operating systems nailed this aspect of separating user files from the OS a long time ago, insisting that all meat-bag data is stored (originally) in a dedicated/home folder, and in recent years on a /home partition. This enables the OS files to be nuked from orbit, reinstalled, and the world keeps on turning, because user files and config files are safely stored away from the detonation site. Windows 2000 did introduce something similar, but there's still an unholy mishmash of files all over the place. It's annoying.


Backup and Restore (Windows 7)
Control Panel › System and Security › Backup and Restore (Windows 7)
Search Co...
Control Panel Home
Create a system image
Create a system repair disc
See also
Security and Maintenance
File History
Create a system image
Where do you want to save the backup?
A system image is a copy of the drives required for Windows to run. It can also include additional drives. A system image can be used to restore your computer if your hard drive or computer ever stops working; however, you can't choose individual items to restore.
On a hard disk
Storage (D:) 1.41 TB free
On one or more DVDs
DVD RW Drive (E:)
On a network location
Select...
Next
Cancel

The targets in Windows Backup still include DVDs.

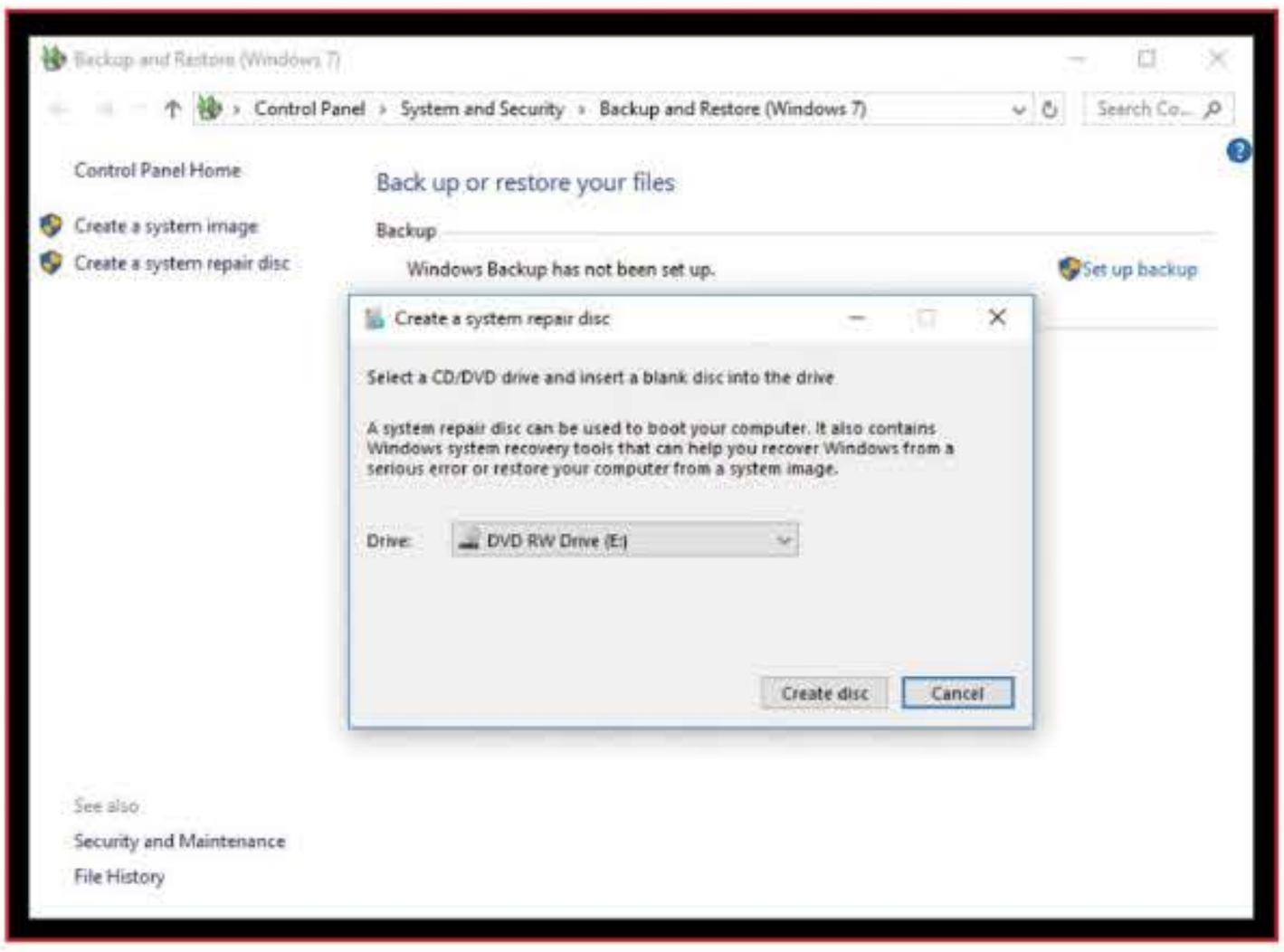
THE MICROSOFT WAY

We're going to kick off by looking at the built-in Windows System Image tool. Microsoft tried to push people away from system images when it introduced Windows 8, in its not so subtle way of killing off Windows 7 Backup and Restore, which was originally introduced in Windows Vista. After much Gen-X moaning, Microsoft restored the system to Windows 8.1, and it remains tucked away in Windows 10 under the Control Panel section in "System and Security → Backup and Restore (Windows 7)."

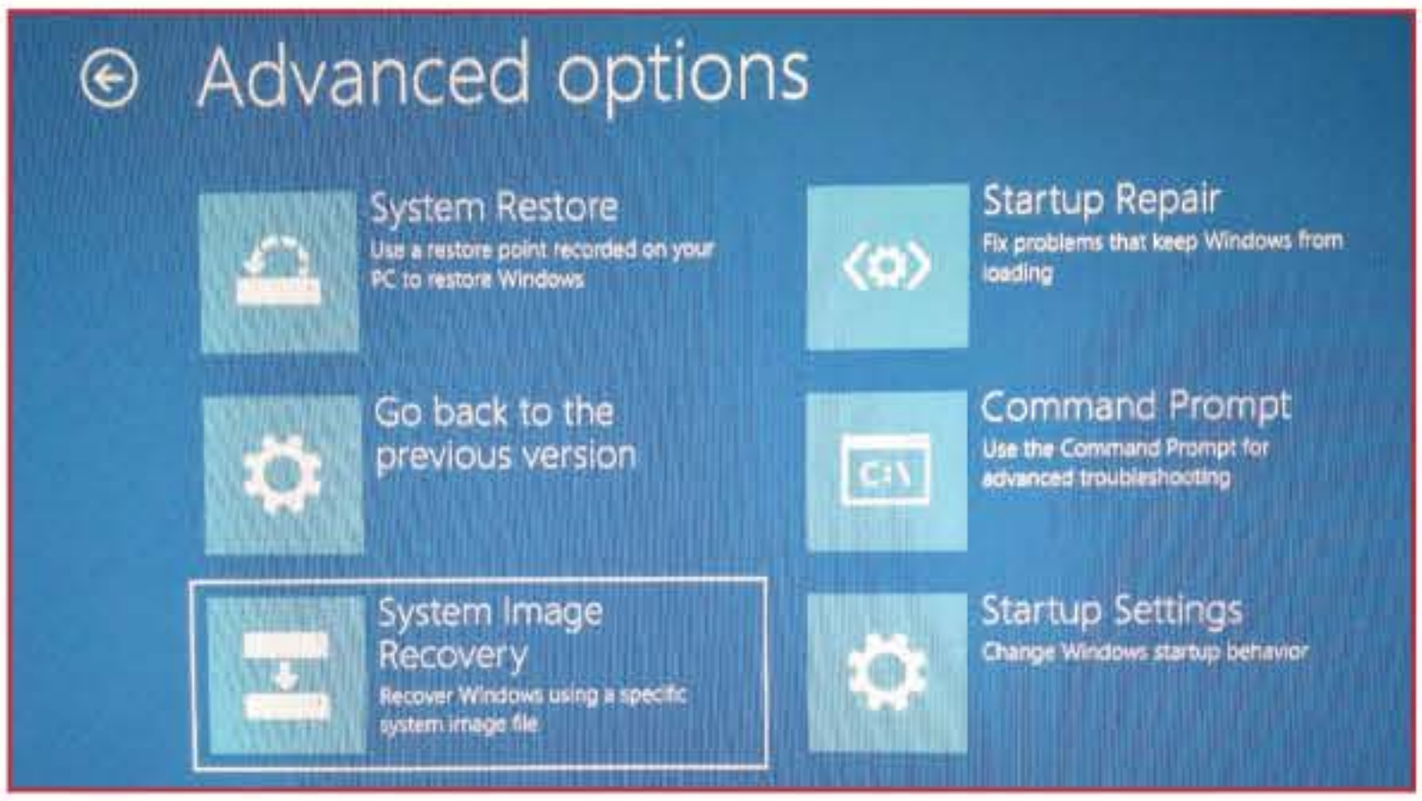
In its favor, it's pretty straightforward to use, uses shadow copy to run in the background as you work, and the recovery (usually) works as part of the standard recovery mode options. The "usually" comment there is inserted as we have run into issues restoring images made under different versions of Windows—as in, it won't do that. Technically (and actually), you should make a recovery disc as a catch-all—you're prompted to do this when an image is completed.

Limitations with Windows System Image include: minimal options (it only images the entire system drive, and you can't restore individual files after); it only backs up to the root of a selected backup drive, and it only allows one image on there; it insists on a network username and password for network shares, even if they have public access rights (in this case, you need to provide the remote system's standard username and password); and, as mentioned, it doesn't support incremental backups, so it always takes a long time to run.

Creating a disk image with Microsoft System Image is pretty easy, but you need a separate internal drive, a spare external


Backup and Restore (Windows 7)
Control Panel › System and Security › Backup and Restore (Windows 7)
Search Co...
Control Panel Home
Create a system image
Create a system repair disc
Back up or restore your files
Backup
Windows Backup has not been set up.
Set up backup
Create a system repair disc
Select a CD/DVD drive and insert a blank disc into the drive
A system repair disc can be used to boot your computer. It also contains Windows system recovery tools that can help you recover Windows from a serious error or restore your computer from a system image.
Drive: DVD RW Drive (E:)
Create disc
Cancel
See also
Security and Maintenance
File History

It's really handy having a rescue disc to hand in case of emergency.


Advanced options
System Restore
Use a restore point recorded on your PC to restore Windows
Startup Repair
Fix problems that keep Windows from loading
Go back to the previous version
Command Prompt
Use the Command Prompt for advanced troubleshooting
System Image Recovery
Recover Windows using a specific system image file
Startup Settings
Change Windows startup behavior

If everything goes to plan, recovery is a smooth process.

drive, a big stack of DVDs, or a network share to which you know the username and password. Got that sorted? Good!

In "Search," type "Control," and select "Control Panel." Under "System and security," click "Backup and Restore (Windows 7)," and click "Create a system image" on the left. It scans for what it considers viable backup targets. An external drive or network share would be best, though any internal drive is fine; as mentioned, though, for any network share, even if it's set for guest access, you need to provide a suitable username and password. If everything appears to work, click "Next." You're provided with an estimate of the space requirements and a "Start backup" button. Hit that, and you can continue life as normal, while the drive is imaged in the background.

To recover your PC, you have two options: reboot using a recovery DVD, or start Windows in Recovery mode. If Windows runs, open the "Start" menu, type "Recovery," and choose "Recovery options." Select "Restart now" under "Advanced startup." Choose "Troubleshoot → Advanced options → System image recovery." Windows then reboots into Recovery mode. You need the drive with the system image on plugged in to your computer. Follow the prompts, and your system tis restored.

THE OPEN WAY

So, the Microsoft tool is limited and slow, but it has saved our bacon a couple of times over the years. We look at other proprietary options in the box below, but we'd like to focus on the long-standing industry tool Clonezilla. In development since in 2007, it's an enterprise-class disk-imaging and restore tool, with support for over 20 filesystems, over six operating system types, and sector-to-sector copy for those it doesn't support. It has full network support, a client-server mode, and supports full encryption of its images. It's beyond the scope of this article, but it also supports Multicast for multi-clone/restore to networked systems, with PXE and WoL support.

That's all nice, but it means Clonezilla is more complex to use. It's not helped by the fact that it has its roots in the Linux garden, so text-based interfaces and indecipherable drive names are the order of the day. The flip side is that it's super-flexible, and free to use anywhere and on anything. And once you've run through the menu systems, you soon learn what's important and what can be ignored.

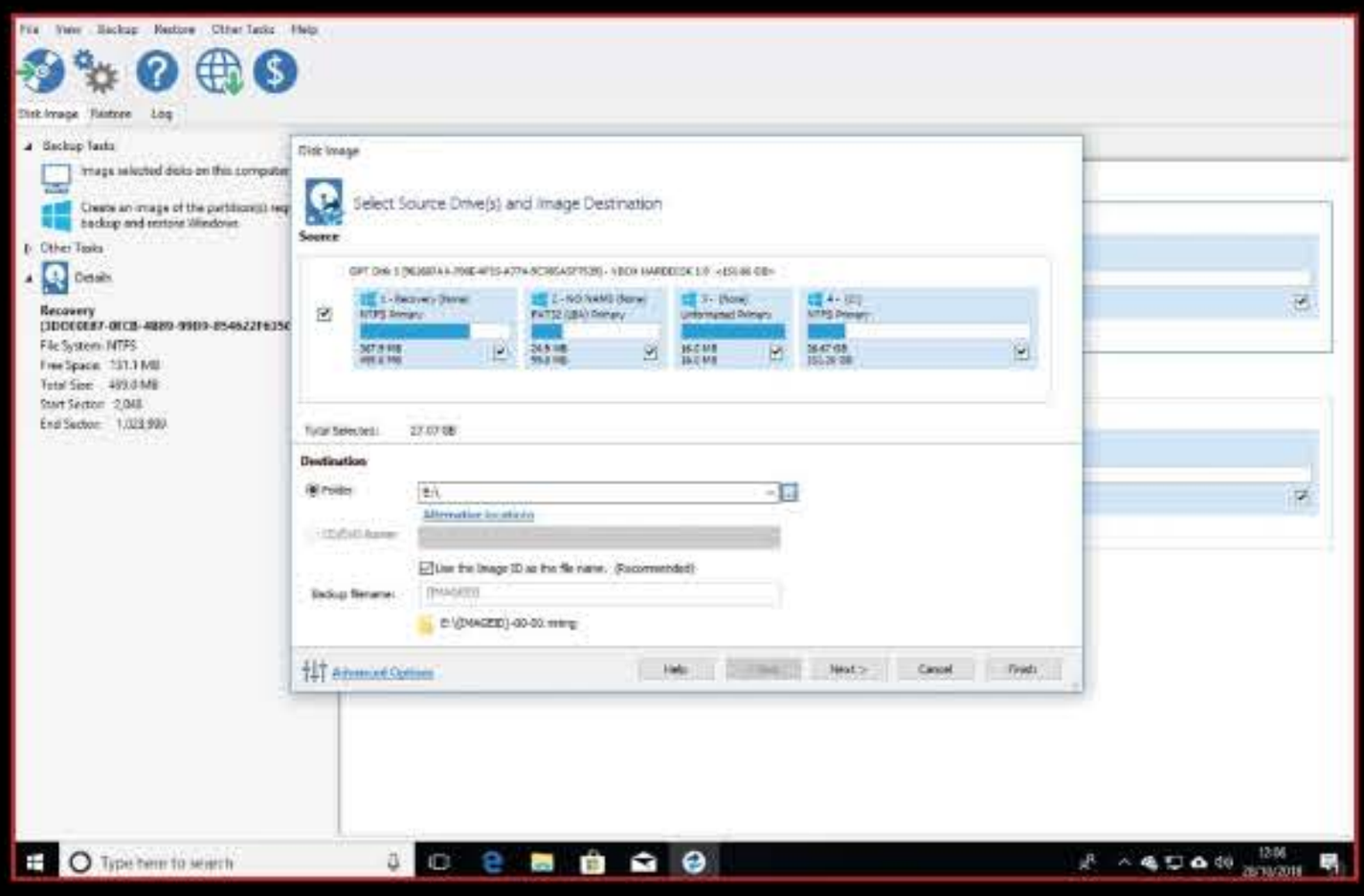
Clonezilla is a "live disc" OS, which means you grab the ISO image from www.clonezilla.org, and write it to either

GIVE ME A GUI!

We're the first to admit that Clonezilla isn't the prettiest thing to look at, nor the easiest in terms of understanding what it's asking you half the time. In the past, both www.easeus.com and www.macrium.com have offered solid free imaging tools, and certainly sell excellent commercial solutions.

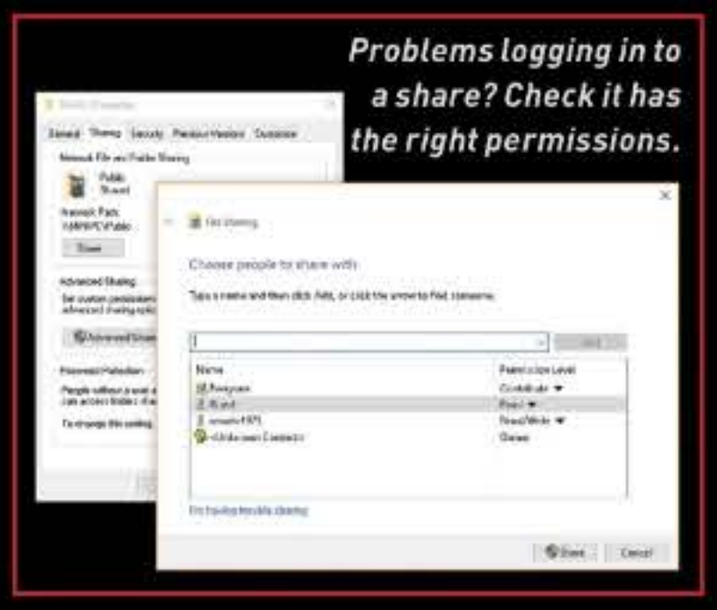
If you're looking for a free option, Macrium Reflect Free Edition is probably your best bet. Once installed—there's an initial 5MB installer download, followed by a 800MB main download—you can simply select "Backup → Windows," and it backs up your full boot drive (boot, Windows, and recovery partitions) in a simple fashion. It also supports differential backups, so once the main imaging is finished, further backups take much less time.

Unlike Clonezilla, which has to be run off a bootable device, you need to create a recovery disc with Macrium Reflect. You can do this if your system fails to boot,



Differential backups, shadow copy, and a rescue environment, all in one.

but it's more useful to have the system in place beforehand. This is done via "Other Tasks → Rescue Media Wizard," and Macrium calls it a Windows PE rescue environment. Click "Change PE Version" to see the issue with older versions of Windows; effectively, Windows 10/8.1/8/7/Vista/XP need different versions to work, which complicates restoring older versions.



DO THE SAMBA

Clonezilla supports a number of networked backup and restore options—the one most likely to be relevant to you is Samba. That's the crazily named open-source implementation of the Windows networking protocol. The option pops up after you pick the type of backup/restore mode to use, and at the Image Directory point. Choose "samba_server," then the next few steps require you to know the IP address of the target system, plus have a Windows username and password for it. We also suggest creating a public/guest-accessible folder to save the images to. You still need the username and password for the main account, or create a new user for the backup task.

If you don't know the IP address, assuming you can access the target networked machine, type "ipconfig" in a command prompt, then press Enter—IPv4 is the address you need. Alternatively, use a tool such as Fing on an Android phone to scan your network and return the IP address of the PC.

After selecting "samba_server," choose "DHCP," as that should be how your network is configured to hand out IP addresses. It runs a scan, then asks for the IP address or FQDN of the server—you need the IP address of the target PC. Ignore the "Domain" request. Replace "administrator" with the username, replace "/images" with the shared folder name—"/public," for example. When it asks for the Samba version, the default 1.0 is fine. Select "Auto use system default" for security. At this point, it asks for the password so it can try to log in.

If you get login errors, check you typed the password correctly (it's case-sensitive). Also check permissions on the Windows share, and that it is accessible by the user account—one way to check is to right-click the shared folder, then select "Properties → Sharing → Share," and check the permissions.

a CD, DVD, or USB stick. You then boot your system off that. Get the "Alternative Stable" image, aka Ubuntu-based build, from www.clonezilla.org/downloads.php—it's about 220MB. This version can avoid potential UEFI boot issues on new systems. If you want to write this to a USB stick, the latest tool to do that is Etcher.io. Gather all that together, write it to the USB stick, and come back when you're ready.

Now work out how to boot your PC from a USB device—many systems offer an early "Boot" menu, accessed by tapping F9 (HP), F12 (Dell, Lenovo), F8 (Amibios), or F11 (Award BIOS) while it runs the power-up POSTs; otherwise you need to hit Del, and fiddle with your boot device priority settings in the BIOS/UEFI.

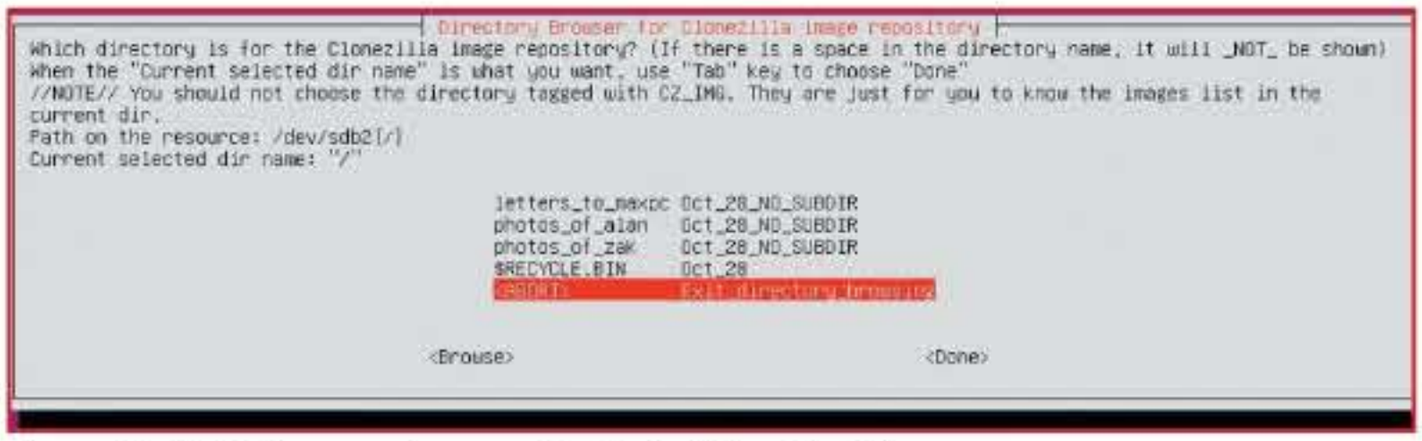
If all has gone well, you're presented with the glorious text-based screen shown below. A rule of thumb here is to use the defaults—you can't really go too wrong. We're going to take you through creating an image of your boot drive and restoring that. We'll talk about live imaging drive-to-drive, and in the box on the left, we cover networked imaging, because Samba networking takes a couple more steps to set up.

Going through the menu, "800x600" is more than enough pixels for anyone, then "English language," "Default US keyboard layout," and "Start Clonezilla." Then you land at the first menu of import. Use the up/down arrow keys to move up and down; switch between "<OK>," "<CANCEL>," and main menu options with the Tab key; and if you need to select multiple items, do that with the space bar.

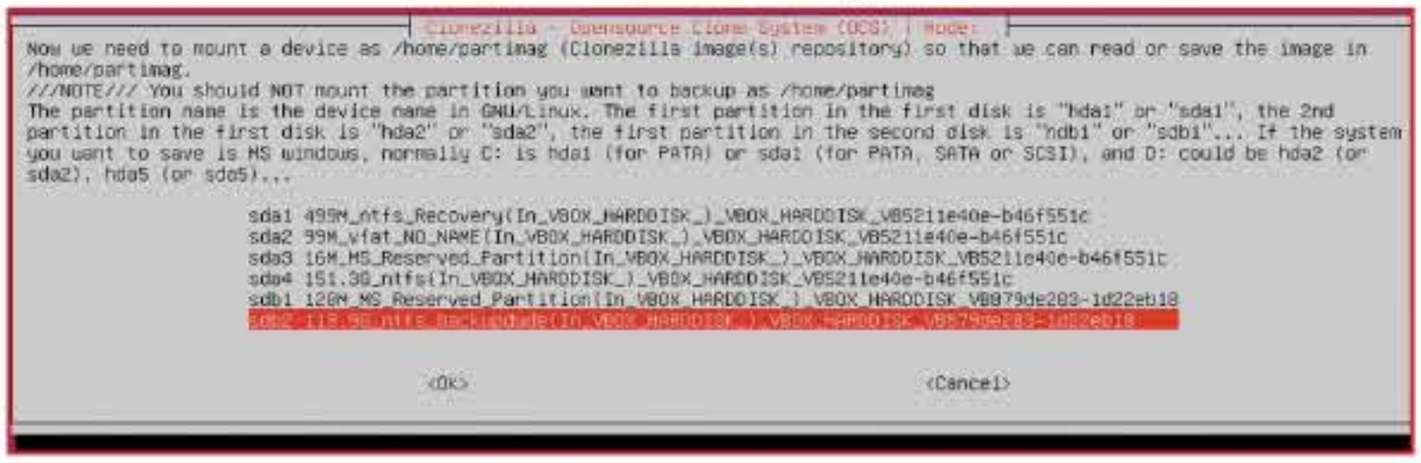
Choose "device-image" or "device-device" mode—we're not covering the other options. We're selecting "device-image" first, so hit Enter. Next, choose the location of the image file; we're using "local_dev" (local storage device), so tap Enter. For network access, you'd select "samba_server," while if you have accounts for Amazon S3 or OpenStack, they would be useful for remote backups.

At this point, it prompts you to plug in your USB device. Wait five seconds, then press Enter. It now lists all the suitable devices it can detect; this should include the source drive you want to image, and the target drive where you want to store the image. The list uses modern Linux parlance, such as "/dev/sda VBOX_HARDDISK VBOX_HARDDISK_<LONG HEX NUMBER> 163GB." The initial "/dev/sdX" is the human-readable system label for the drive; the first name is the detected hardware device name; and the long name containing hexadecimal is the unique OS label, ending with the total capacity.

If those look correct, press Ctrl-C, and Clonezilla scans for partitions. This results in another overly complex-looking list. You should recognize the device labels


Directory Browser for Clonezilla image repository
Which directory is for the Clonezilla image repository? (If there is a space in the directory name, it will _NOT_ be shown)
When the "Current selected dir name" is what you want, use "Tab" key to choose "Done"
//NOTE// You should not choose the directory tagged with CZ_IMG. They are just for you to know the images list in the current dir.
Path on the resource: /dev/sdb2(/)
Current selected dir name: "/"
letters_to_maxpc Oct_28_NO_SUBDIR
photos_of_alan Oct_28_NO_SUBDIR
photos_of_zak Oct_28_NO_SUBDIR
$RECYCLE.BIN Oct_28
<Brouse>
<Done>

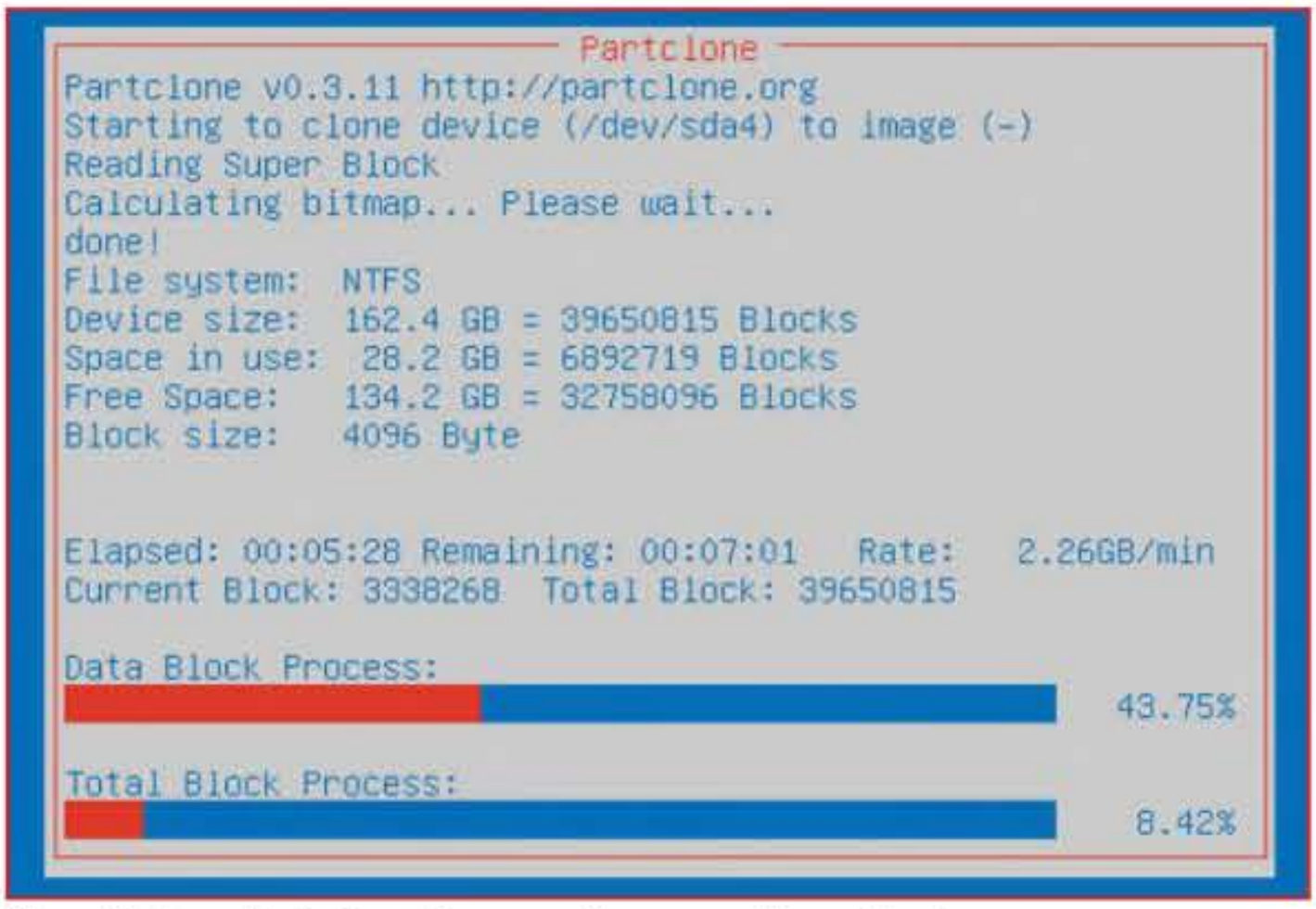
Clonezilla's file browser is super-basic, but does the job.


Clonezilla - Opensource Clone System (OCS) | Mode:
Now we need to mount a device as /home/partimag (Clonezilla image(s) repository) so that we can read or save the image in /home/partimag.
///NOTE/// You should NOT mount the partition you want to backup as /home/partimag
The partition name is the device name in GNU/Linux. The first partition in the first disk is "hda1" or "sda1", the 2nd partition in the first disk is "hda2" or "sda2", the first partition in the second disk is "hdb1" or "sdb1"... If the system you want to save is MS windows, normally C: is hda1 (for PATA) or sda1 (for PATA, SATA or SCSI), and D: could be hda2 (or sda2), hda5 (or sda5)...
sda1 499M_ntfs_Recovery(In_VBOX_HARDDISK_)_VBOX_HARDDISK_VB5211e40e-b46f551c
sda2 99M_vfat_NO_NAME(In_VBOX_HARDDISK_)_VBOX_HARDDISK_VB5211e40e-b46f551c
sda3 16M_MS_Reserved_Partition(In_VBOX_HARDDISK_)_VBOX_HARDDISK_VB5211e40e-b46f551c
sda4 151.3G_ntfs(In_VBOX_HARDDISK_)_VBOX_HARDDISK_VB5211e40e-b46f551c
sdb1 128M_MS_Reserved_Partition(In_VBOX_HARDDISK_)_VBOX_HARDDISK_VB079de203-1d22eb18
<OK>
<Cancel>

Take your time, and you'll find that the device list does make sense.

Clonezilla - Opensource Clone System (OCS) | Mode: savedisk
Choose local disk as source.
The disk name is the device name in GNU/Linux. The first disk in the system is "hda" or "sda", the 2nd disk is "hdb" or "sdb"... Press space key to mark your selection. An asterisk (*) will be shown when the selection is done
sda 163GB VBOX HARDDISK VBOX HARDDISK_VB5211e40e-b46f551c
<OK>
<Cancel>

Use the space bar if you need to multi-select devices.


Partclone
Partclone v0.3.11 http://partclone.org
Starting to clone device (/dev/sda4) to image (-)
Reading Super Block
Calculating bitmap... Please wait...
done!
File system: NTFS
Device size: 162.4 GB = 39650815 Blocks
Space in use: 28.2 GB = 6892719 Blocks
Free Space: 134.2 GB = 32758096 Blocks
Block size: 4096 Byte
Elapsed: 00:05:28 Remaining: 00:07:01 Rate: 2.26GB/min
Current Block: 3338268 Total Block: 39650815
Data Block Process:
43.75%
Total Block Process:
8.42%

Clonezilla is pretty fast, and has a good time-remaining estimate.

"sda," "sdb," and so on that denote drives, while the partitions on each drive are numbered "sda1," "sda2," and so on for one drive, and "sdb1," "sdb2," etc. for the next drive. Each following label consists of "<capacity>_<file system>_<drive label>_<device name>_<OS Unique ID>." Select the target drive to save the image to; if you've named it, look for the "<drive label>" section. Select it, then press Enter.

You're presented with a "Directory Browser." If your backup drive is blank, it just has a confusing "<ABORT>" selection, but if you have sub-directories, these are listed and selectable. Don't worry—each image creates its own folder anyway. Tap Tab twice to select "<DONE>," then press Enter to use the root to store images.

Select "Beginner" mode, then we need to select the backup style. To keep things simple, we're going to focus on "savedisk," as in the entire drive—for a typical Windows boot drive, this is three partitions, which you want to save: boot partition, OS partition, and a recovery partition. If you're recovering your image, select the "restoredisk" or "restoreparts" option—notice the "1-2-mdisks" option, which enables multi-disk restoration if you're doing a mass clone. Press Enter to get this show on the road. Keep the default date-based name. Finally, select the drive (or partitions, if that's the option you've chosen) to image, then press Enter.

There's a final batch of options to go through. Choose "-sfsck" to skip disk checking (it doesn't work well on NTFS filesystems anyway); choose to verify the final image; encrypt the image for security if you want, but you need a strong password; and it offers to power down when done. Hit Enter twice to get started. There's a final "Press (y/n)" to get started, before a detailed progress display is shown. Even on older spinning drives, imaging a boot drive shouldn't take much longer than 15 minutes, unless its capacity is in the terabyte range. SSD scenarios are significantly faster.

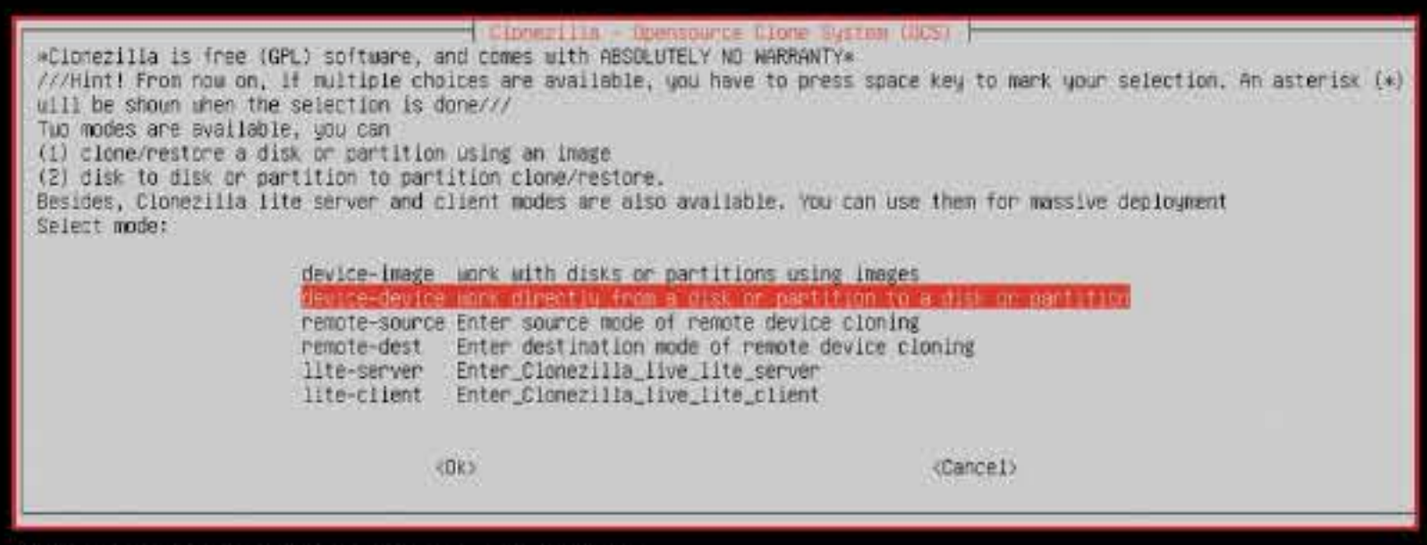
Restoration of a drive is exactly the same—the advantage for Clonezilla is the images are always compatible, you can easily get a fresh ISO to boot from, and images can be stored anywhere, even in the cloud—just after the "Beginner" mode selection, choose "Restoredisk" mode.

Disk imaging isn't a cure-all backup solution, but it can help get a system back up faster than reinstalling, and is a real time-saver for deployment scenarios.

DRIVE CLONING

It's worth taking a quick detour to specifically cover drive migration, cloning, or drive-to-drive imaging. With SSD prices currently falling through the floor, if you've got an older system still running spinning rust or stuck on an outdated, smaller SSD, this is the ideal time to migrate it to a larger, faster new SSD. Copying system files can be off-putting, but with Clonezilla, it's a cakewalk.

Of course, there are some points we need to cover first. The new drive has to be as large as the original drive, at least in terms of space. You can use the Windows Disk Management console to attempt to shrink partitions, but you may need to delete files to make room, too. Search for "Disk Management," and select the "Create and format" option. Right-click your C: drive, and choose "Shrink" to see if it'll reduce enough in size. If you're moving from an old HDD to a new SSD, this could very likely be the case; you might be better mass-moving a host of user files to a backup drive, and taking it from there.


Clonezilla - Opensource Clone System (OCS)
Clonezilla is free (GPL) software, and comes with ABSOLUTELY NO WARRANTY
///Hint! From now on, if multiple choices are available, you have to press space key to mark your selection. An asterisk (*) will be shown when the selection is done///
Two modes are available, you can
(1) clone/restore a disk or partition using an image
(2) disk to disk or partition to partition clone/restore.
Besides, Clonezilla lite server and client modes are also available. You can use them for massive deployment
Select mode:
device-image work with disks or partitions using images
device-device work directly from a disk or partition to a disk or partition
remote-source Enter source mode of remote device cloning
remote-dest Enter destination mode of remote device cloning
lite-server Enter_Clonezilla_live_lite_server
lite-client Enter_Clonezilla_live_lite_client
<Ok>
<Cancel>

Migrating an entire drive is very easy to do.

You need to power down your system and attach the new drive to which you want to migrate. To avoid catastrophic data loss, you might want to remove any unnecessary drives, to avoid wiping them by mistake.

You need to use Clonezilla's device-to-device mode, rather than the individual partition option—this is the "disk_to_local_disk" option, rather than "part_to_local_part." It might seen cunning just to duplicate the Windows partition, but that omits the bootloader—either MBR or GTP—leaving the clone unbootable.

The next step lists all the detected storage devices. It's vital that you choose the correct "Source," and then the correct "Target," otherwise you'll nuke your boot drive. Once you confirm, Clonezilla starts duplicating the entire device. If the new device is larger, check "Disk Management" to see whether it will expand the partition to fill any free space.

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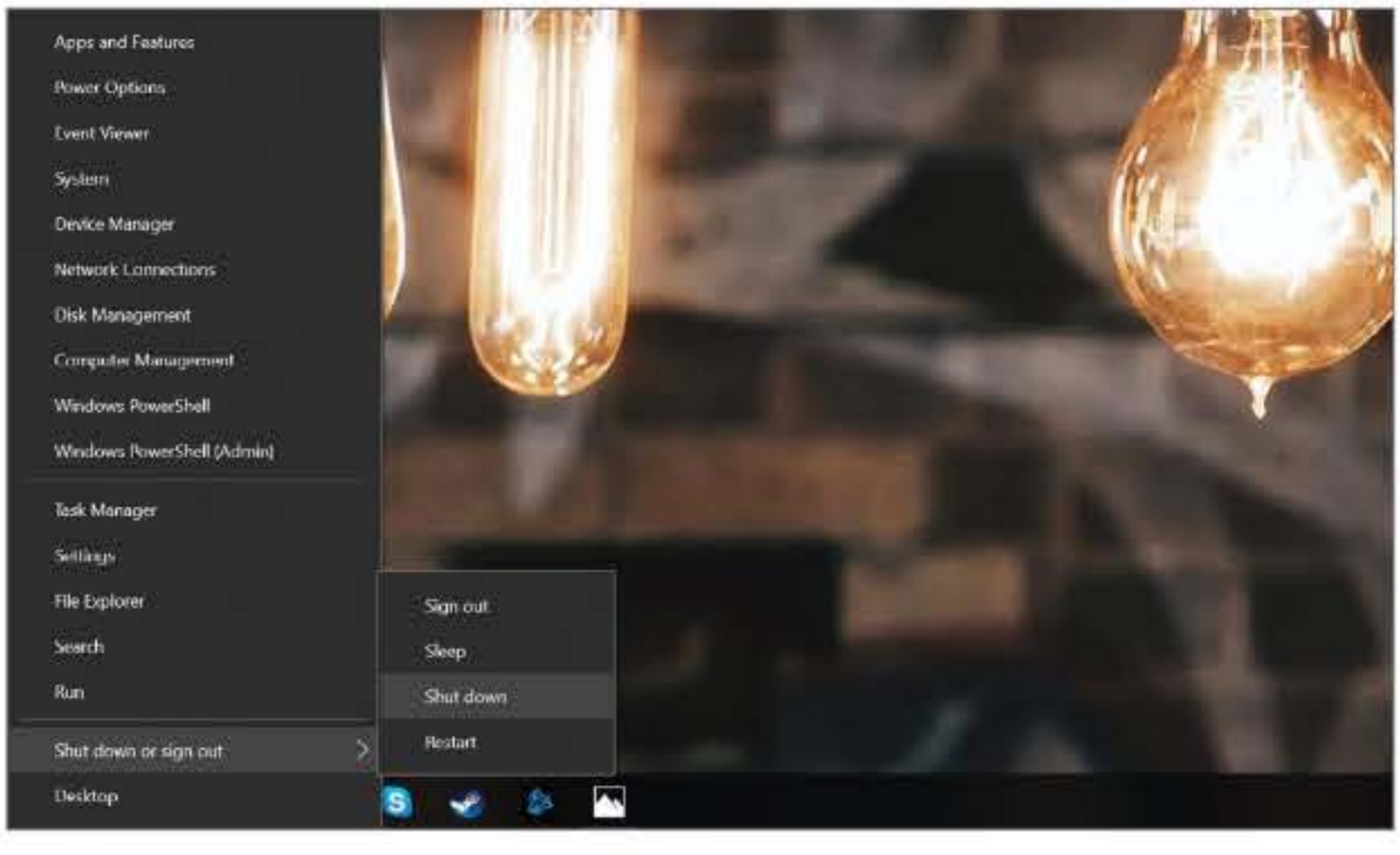
HOW TO

STEP-BY-STEP GUIDES TO IMPROVING YOUR PC

TIP OF THE MONTH



POWER USER START MENU

Ever needed to get to the Power menu in the Start menu? It's certainly a quicker way of shutting down, that's for sure. For a quick, digestible Start menu, move down to the Windows icon, and simply right-click. Windows then opens up the Power menu, allowing quick access to a number of features, including better shutdown options. $Free

MAKE – USE – CREATE

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ZAK STOREY
DEPUTY EDITOR

WITCH HUNT

Despite the fact that many of us are competitors, you'll often find us journos working together to get to the bottom of hardware issues, news, and rumors. And it's important we do, because not only do we learn by riffing off each other, but it also informs our content, and provides you with better-balanced coverage.

Lately, though, we've been seeing some journalists call out folks publicly over results they deem "fake" or "paid for," because it gets a reaction from their audience. Instead of discussing it in private, they're publicly shaming the journos in question. Don't get me wrong, calling out fake BS is important, but calling out slight discrepancies in results that you disagree with, just to generate a reaction from your viewers—where do we begin?

Well, how about the variables involved in benchmarking? From your test bed to the benchmarks you choose, the software versions of those benchmarks, the BIOS configs, and even the way you measure the results, the number of possible setups is ridiculous. Couple that with the silicon lottery, and you get the picture.

It's obvious that you're going to see different results from different reviewers. So, as a consumer, you need to be looking at multiple publications before you make a solid decision.

↘ submit your How To project idea to: comments@maximumpc.com

IFIXIT presents:

AUTOPSY

THIS MONTH WE DISSECT...

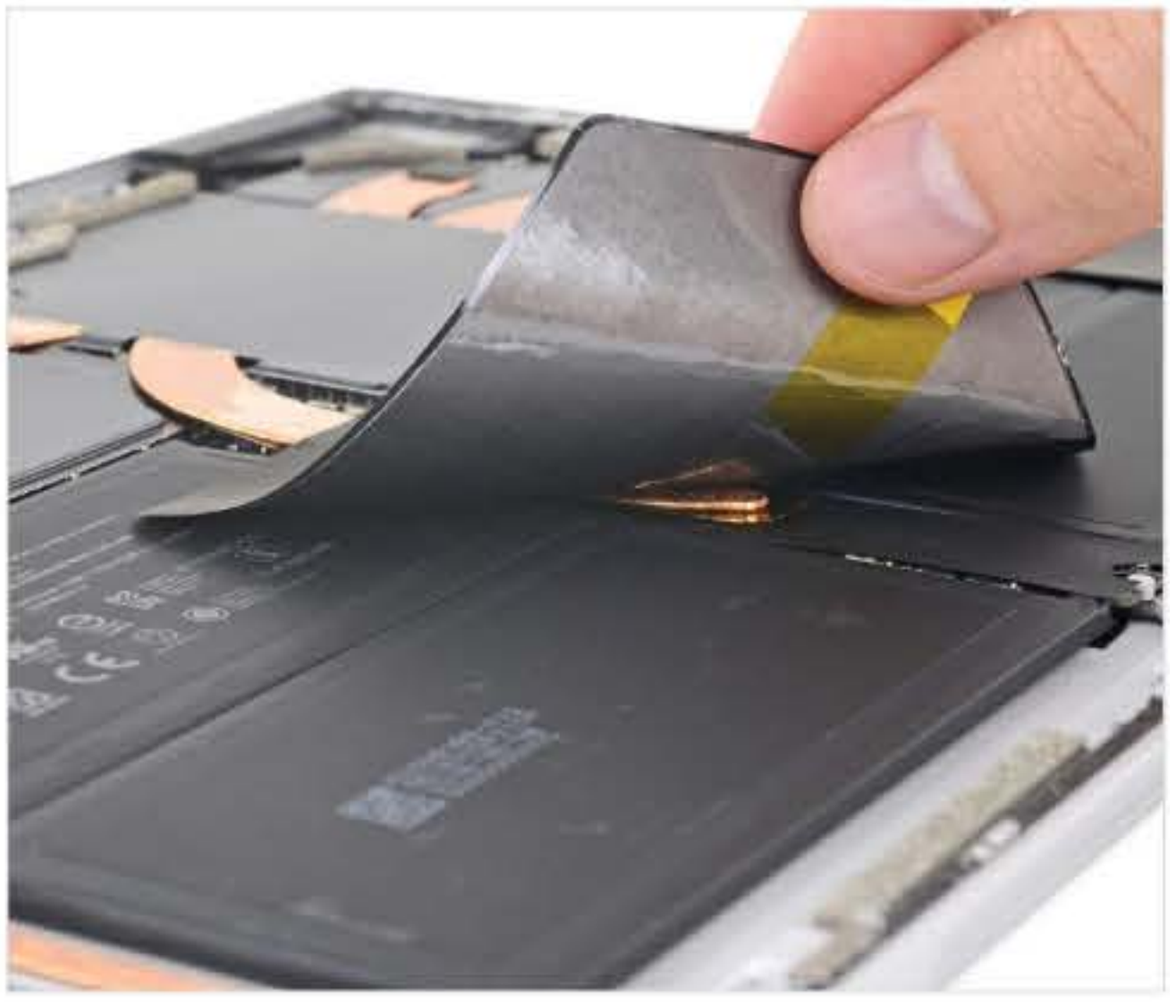
Microsoft Surface Pro 6

You need to be very patient when opening Microsoft's latest.

About iFixit

iFixit is a global community of tinkerers dedicated to helping people fix things through free online repair manuals and teardowns. iFixit believes that everyone has the right to maintain and repair their own products. To learn more, visit www.ifixit.com.

These pads can be found at the end of the heat spreaders. They're a bit odd.



BACKGROUND

Microsoft has decided once again to grace its Surfaces with numbers. This year's Surface Pro 6 comes with a sleek new black paint job and the first ever quad-core processor in a Surface device. What else will we find inside? Let's find out!

MAJOR TECH SPECS

- 12.3-inch 2736x1824 (267 ppi) PixelSense display
- 8th-Gen quad-core Core i5 with Intel UHD Graphics 620
- 8GB RAM (16GB optional)
- 128GB solid-state storage (256GB, 512GB, or 1TB options)
- 8MP rear-facing camera with 1080p video, and 5MP/1080p front-facing Windows Hello camera
- USB 3.0, microSDXC, Mini DisplayPort, SurfaceConnect, 3.5mm audio port, 802.11a/b/g/n/ac, and Bluetooth 4.1

KEY FINDINGS

- On the outside, not much has changed. Still the same case, hinge, and relatively healthy number of ports. Noticeably absent, however, is the USB-C port that found its way on to the Surface Go. The Surface Pro series has a few different configurations, all with upgraded adhesive as standard.
- Luckily, we've got a recipe for screen separation success:
  Step 1: Apply iOpener liberally.
  Step 2: Grab an opening pick and suction handle, and fight for dear life through Microsoft's gauntlet of adhesive.
  Step 3 (optional): Get impatient, break screen.
  Fortunately, we don't run into any surprises as we free the display—everything's much the same as before, save for an extra display cable compared to the Surface Go.
- It seems Microsoft has been meddling with its passive cooler—it looks like last year's, but with an extra pipe down the left side, plus some funky heat-spreading pads.
- Looking south, the similarities continue, with a quad-cell battery taking up most of the case. On the plus side, all the screws so far are standard Torx. Let's twirl them out! The Surface Pro 4 had a copper heat spreader, but these look like graphite. Now we're free to remove the heatsink.
- We've come to that inevitable junction in any Surface teardown: Take out the heavily glued battery, or leave it be? Considering there are no stretch release battery tabs, we opt to let the beast slumber for now. It weighs in at 45Wh (7.57V x 5,940mAh), exactly the same at last year.
- Really scraping the bottom of the barrel case, hoping for something new, we pull out the speakers and cameras. The cameras are still hidden under the bracket holding the antennas (which are incredibly easy to mangle upon opening), while the speakers are still corner-mounted triangles for that surround-sound feel.
- Repairability score: 1 out of 10 (10 is easiest to repair). To the extent that screws are used, they are all standard Torx fasteners. This tablet still has a headphone jack, which is modular and replaceable, if you can get to it. All repairs require first removing the display assembly—which is stubbornly glued in place, expensive, and prone to shattering. The battery is firmly glued in place, with its connector pinned under the motherboard—requiring near-total disassembly for service. Once upon a time, Surface Pro storage was removable—but not in this version. Complex construction makes all disassembly and reassembly tedious in comparison to other tablets.

Create Secret and Secure Web Servers

YOU'LL NEED THIS

A LINUX PC
This needs to run OpenVPN.

LET'S FACE IT: There's always a shady organization or overreaching government wanting to hack your system and spy on your life. Keeping your Internet activity secure can be difficult, especially if you've got servers you want hidden from everyone except a few trusted individuals. That's the point of what we're going to do in this article. We're going to show you how to access your own web server from anywhere in the world, without anyone knowing about it.

There are several ways you can create secure connections between two computers, but for our purposes, we're going to use OpenVPN. It's considered one of the best solutions available, because it's based on sound encryption algorithms, it's open source, and it's highly configurable. It creates an encrypted tunnel between two computers using OpenSSL, which makes it possible for data to be transferred without being compromised. **–DENNIS JARECKE**

A

```
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP group default qlen 1000
    link/ether b0:6e:bf:61:43:a3 brd ff:ff:ff:ff:ff:ff
    inet 192.168.1.147/24 brd 192.168.1.255 scope global eth0
       valid_lft forever preferred_lft forever
    inet6 fe80::b26e:bfff:fe61:43a3/64 scope link
       valid_lft forever preferred_lft forever
3: wlan0: <BROADCAST,MULTICAST> mtu 1500 qdisc noop state DOWN group default qlen 1000
    link/ether e8:d1:1b:99:d1:c1 brd ff:ff:ff:ff:ff:ff
5: tun0: <POINTOPOINT,MULTICAST,NOARP,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UNKNOWN group default qlen 100
    link/none
    inet 10.0.0.1/24 brd 10.0.0.255 scope global tun0
       valid_lft forever preferred_lft forever
```

1 THE BASICS

Here's the scenario: Imagine you're running OpenSUSE Leap 42.3 with a website you want to access without anyone knowing it exists. The site is up and running, and working great behind your router.

» But now you want to access the server from anywhere in the world. You could go to your router and route HTTP traffic to your Linux machine, but that would expose your computer to every hacker on the planet. Alternatively, you can create an OpenVPN tunnel between your laptop and desktop computer that only you have access to. This keeps your activity hidden, because you're not connecting to ports 80 or 443, and your traffic is encrypted for maximum security. Let's see how you can implement this for yourself.

» Setting up OpenVPN has lots of steps, and the first time you do it, it's difficult. There are technical concepts you need to understand, and usually up to 10 files you need to create. Plus, there are lots of configurations that are talked about online, and each one has its own set of steps that may not be applicable to our situation here. If this is new to you, focus on routing tables and OpenSSL's public key infrastructure to understand what's going on.

» Here's a summary of what happens: In the configuration files, you designate a network for OpenVPN (such as 10.0.0.0/24), and the OpenVPN software creates a virtual network adapter for it (such as tun0). OpenVPN modifies the Linux routing table to send 10.0.0.0/24 packets through tun0 [Image A].

B

2 VIRTUAL AND PHYSICAL ADAPTERS

Outgoing packets are encrypted with OpenSSL at the virtual network adapter (tun0), forwarded via the routing table to the physical adapter (eth1), and sent out to the Internet. Incoming packets arrive at the physical adapter (eth1) on port 1194, are forwarded to the virtual adapter (tun0), decrypted with OpenSSL, then sent to local programs, such as Apache. All you have to do is interact with the IP address of the virtual network adapter created when OpenVPN starts. In other words, you treat 10.0.0.0/24 as any other external network, but with the confidence that your packets are secure.

» The OpenVPN documentation says you may need to tell Linux to forward traffic between Ethernet devices: `sysctl -w net.ipv4.ip_forward=1` gets forwarding working between your physical and virtual adapters.

» It's important to note that the firewall sits between your virtual network adapter and local programs, such

as Apache, and between the virtual adapter and the physical adapter [Image B]. The diagram shows the Input, Output, and Forward chains in the filter table, but Prerouting and Postrouting chains can also impact your configuration if you're not careful.

» The OpenVPN authentication, encryption, and decryption occurring at tun0 [Image C] is handled by OpenSSL. OpenSSL is a general-purpose cryptography library for creating and managing a public key infrastructure (PKI). While this may be familiar, let's review it, because it's a major component of OpenVPN, and a big step in the configuration process.

» When two people want to communicate privately, they create private and public keys, then exchange their public keys while keeping their private keys secret. Messages are encrypted with public keys, and can only be decrypted with the matching private key. Messages can be signed with a private key and verified with a public key. This means messages can be encrypted and authenticated in one easy framework. Public keys are often referred to as a certificate, or cert for short.

» The situation is usually complicated by adding a certificate authority, or CA for short. The CA is a person or business with their own private key and corresponding certificate. The purpose of the CA is to sign other people's certificates. In other words, the CA adds another layer of validation and verification. For OpenVPN, it means you can revoke access to your OpenVPN server at any time.

» It's useful to remember what happens with HTTPS traffic. When calling a secure website via https://, the server sends its certificate signed by a CA to your browser. The browser verifies the signed certificate using the public certificate of the CA. Then the browser generates a key, encrypts it with the server's public certificate, and sends it to the server. Going forward, communication between browser and website is encrypted symmetrically with that key.

» In OpenVPN, both the server and client machines have a CA cert, as well as public and private keys. (You'll see how those are created below.) When a client machine connects to an OpenVPN server, both machines exchange their public certificates and verify them with the CA certificate. Then both computers randomly generate keys, encrypt them with each other's certificates, and exchange them with each other. Data is then encrypted with these keys. These keys are never used bidirectionally, because they are in HTTPS traffic.

3 OPENING MOVES WITH OPENVPN

Now, with all this explanation behind us, let's get you up and running with a real OpenVPN configuration. You need two computers to do this. One acts as a server and the other acts as a client. In this example, the OpenVPN server is an OpenSUSE 42.3 desktop, and the client is a laptop also running OpenSUSE 42.3. Apache should be running and serving up the website you want to keep hidden. Both computers need OpenVPN installed (there's no difference between server and client OpenVPN software), so either download it or install it through your distribution's package manager. On OpenSUSE, run the command `zypper install openvpn`.

4 DIFFIE-HELLMAN

Creating the private keys and certificates turns out to be easy. The OpenSSL commands can be complicated, so there's a program called easy-rsa that makes building the keys and certs quick and simple. Run the command `zypper install easy-rsa` to install it.

» Once installed, navigate to "/etc/easy-rsa" and modify the "vars" file if you want to change any defaults. If this is your first time, leave it alone until you're more comfortable with OpenVPN. Next, run the command `easyrsa init-pki`. This creates the directory "/etc/easy-rsa/pki," where your keys and certs will be created.

» Now run the command `easyrsa build-ca` to create a CA key and cert. Make sure you enter a password and record it in your password manager. Once the command is finished, you'll find you've created "/etc/easy-rsa/pki/ca.crt" and "/etc/easy-rsa/pki/private/ca.key."

» Next, run the command `easyrsa build-server-full server nopass`. It asks for the password to your CA key. This creates "issued/server.crt" and "private/server.key" in the "/etc/easy-rsa/pki" directory. These are your server key and certificate, respectively. Doing this automatically signs your "server.crt" with the "ca.key" file above.

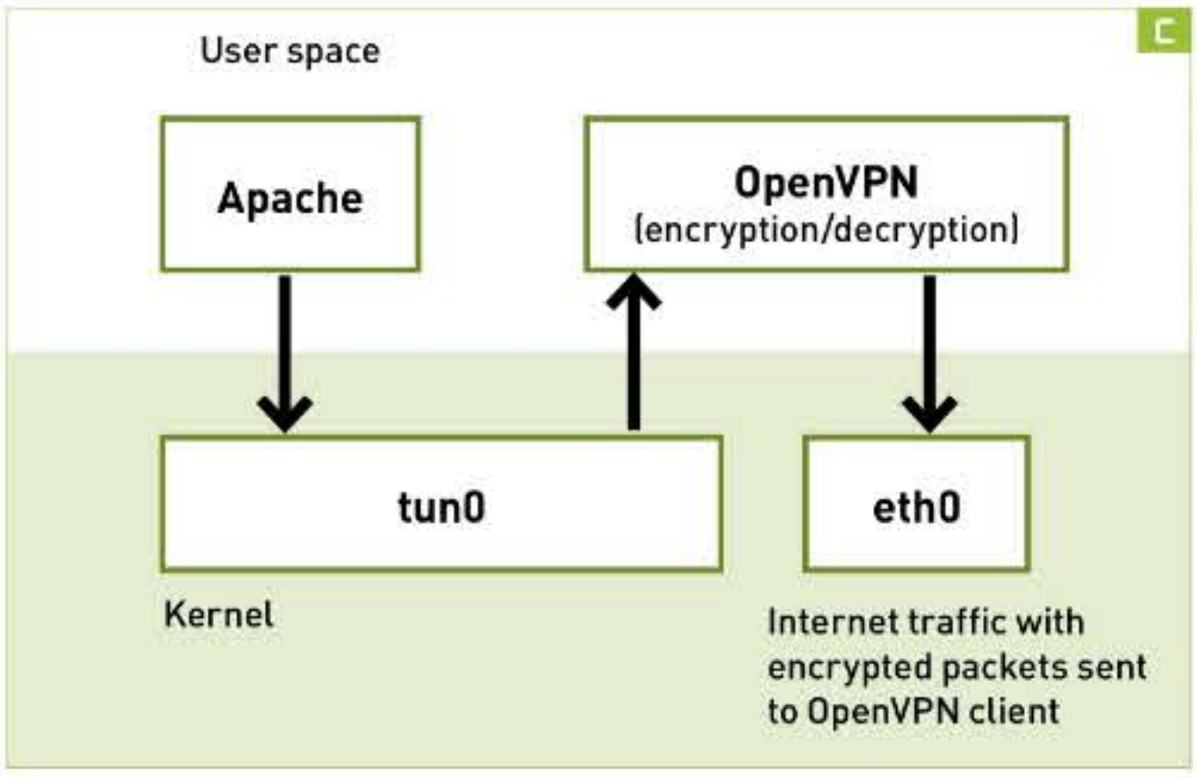
» To create the client key and certificate, run the command `easyrsa build-client-full client nopass`. This

ADD ANOTHER SITE

First, designate an unused IP address in the 10.0.0.0/24 range you want to be attached to your second site. Let's say it's 10.0.0.222 for demonstration purposes. Next, create a virtual host file for the new site in "/etc/apache2/vhosts.d." In it we designate <VirtualHost 10.0.0.222:80> so Apache responds to that IP address. Restart Apache with `systemctl restart httpd`. Finally, add 10.0.0.222 to the tun0 interface by running `ip address add 10.0.0.222 dev tun0`. This attaches the IP address to tun0 so the device responds to it. Verify it's added with `ip address show`. Change your `after.local` command to `openvpn --config /etc/openvpn/server.conf && sleep 10s && ip address add 10.0.0.222 dev tun0` so it's executed on a reboot. The "&&" makes sure the previous command runs properly before executing the next command, and the "sleep" function waits for OpenVPN to create tun0 before adding another IP address to it.

Now you're ready to test your second secret site. Connect to your server as usual, and point your browser to http://10.0.0.222. Your second secret site should be up and running.

C



creates "issued/client.crt" and "private/client.key" in the "/etc/easy-rsa/pki" directory. The "client.crt" file is automatically signed by the "ca.key" file.

» Now let's build the Diffie-Hellman parameters with the command `easyrsa gen-dh`. This creates "/etc/easy-rsa/pki/dh.pem." This is important, because the RSA certificates are used for authentication, but not for encrypting data across the tunnel. It's too slow. With Diffie-Hellman parameters, keys can be quickly created to encrypt data. This is faster and allows for re-keying persistent connections.

» Finally, there's an optional command that adds an additional signature to all SSL/TLS handshake packets for integrity verification. Run "openvpn → genkey → secret ta.key," and place "ta.key" in "/etc/easy-rsa/pki."

Filename	Needed By	Purpose	Secret
ca.crt	Server and all clients	Root CA certificate	No
ca.key	Key signing machine only	Root CA key	Yes
dh.pem	Server only	Diffie-Hellman parameters	No
server.crt	Server only	Server certificate	No
server.key	Server only	Server key	Yes
client.crt	Client only	Client certificate	No
client.key	Client only	Client key	Yes
ta.key	Server and all clients	SSL integrity verification	Yes

» Notice all the keys and certificates have been created on the same machine. It doesn't have to be this way. Ideally, the machine with "ca.key" is designated as a key signing machine, and should be separate from the OpenVPN server. For maximum security, the key signing machine should be off the network. In addition, we could have created "client.key" on the client machine, and submitted a Certificate Signing Request to the key signing machine. After signing, the "client.crt" file would be sent to the client machine. This would be more secure, because "client.key" would never have to leave the client machine.

5 SECURE YOUR SERVER

Copy "ca.crt," "server.key," "server.crt," and "ta.key" to "/etc/openvpn." Now, let's look at a typical configuration. Call the file below "server.conf "and put it in "/etc/openvpn."

```
server 10.0.0.0 255.255.255.0
proto udp
port 1194
dev tun
topology subnet
persist-key
persist-tun
keepalive 10 60
remote-cert-tls client
tls-auth /etc/openvpn/ta.key 0
dh /etc/openvpn/dh.pem
ca /etc/openvpn/ca.crt
cert /etc/openvpn/server.crt
key /etc/openvpn/server.key
cipher AES-256-CBC
user nobody
group nobody
verb 3
daemon
log-append /var/log/openvpn.log
comp-lzo yes
```

» This file opens UDP port 1194 for the physical VPN connection, and creates a virtual "tun" Ethernet device with subnet 10.0.0.0/24. Notice that it references the four files we created. After starting, OpenVPN changes the user and group ID to nobody, for additional protection of the server in case someone manages to get control of an OpenVPN session. A log file is defined, and the recommended verbosity level of 3 is selected. Finally, we LZO compress the data across the tunnel.

» Now let's start the OpenVPN server. If you have a firewall running, open port 1194 with something like `iptables -A INPUT -p udp -m udp --dport 1194 -j ACCEPT`. You can manually start OpenVPN with the command `openvpn --config /etc/openvpn/server.conf`. To start it automatically at a reboot, place the command in "/etc/rc.d/after.local."

» You can verify OpenVPN is running in several ways:

1. Use the top command to find OpenVPN running under user "nobody."
2. Use ifconfig or `ip addr show` to see that tun0 is attached to IP address 10.0.0.1.
3. Use the route or `ip route` command to see that 10.0.0.0 is routed to tun0.

6 CLIENT CONFIG

Configuring your client laptop is almost identical and quick to do. Use the following configuration file:

```
client
remote openvpn-server-hostname-or-ip 1194
proto udp
nobind
dev tun
persist-key
persist-tun
remote-cert-tls server
tls-auth /etc/openvpn/ta.key 1
ca /etc/openvpn/ca.crt
cert /etc/openvpn/client.crt
key /etc/openvpn/client.key
cipher AES-256-CBC
user nobody
group nobody
verb 3
log-append /var/log/openvpn.log
comp-lzo yes
```

» Here we're declaring the laptop as a client machine, with the remote option pointing to the OpenVPN server. Make sure you replace `openvpn-server-hostname-or-ip` with the IP address of your server. Call this "client.conf" and put it in "/etc/openvpn." Next, transfer "ca.crt," "ta.key," "client.crt," and "client.key" to the laptop, and put them in "/etc/openvpn." Finally, start OpenVPN with `openvpn --config /etc/openvpn/client.conf`.

» You can verify OpenVPN is running with the same three methods mentioned above. But to make sure both machines are connected, run `ping 10.0.0.1`, which pings the OpenVPN server from the client. If this works, the two machines are connected via OpenVPN.

7 APACHE ACTION

Remember that the goal is to connect to Apache running on a Linux server through

OpenVPN. There are four more problems that need to be overcome, and it turns out they're easy to solve.

» First, make sure the firewall has a port open with the command `iptables -A INPUT -s 10.0.0.0/24 -p tcp -m tcp --dport 80 -j ACCEPT`. Remember, you specified 10.0.0.0/24 as the OpenVPN network in the "server.conf" file above. This makes sure Apache receives the packets from the OpenVPN network.

» The second problem is configuring Apache to respond to requests coming over the OpenVPN virtual network. Because we don't want anybody to know about this server, we can't rely on DNS to identify it. This means requests to Apache won't have a server name associated with them. To get Apache to respond without a server name, create the virtual host <VirtualHost 10.0.0.1:80> by putting a file called "myserver.conf" in "/etc/apache/vhosts.d," with the same directives that currently work for the host you want to access. You should have Apache up and running, and serving up your website locally, so just use the same directives with the new VirtualHost. However, you need to remove the ServerName entry, because you aren't accessing the website with a server name. Now go to your laptop, start OpenVPN, and type "http://10.0.0.1" into your browser's navigation bar. Your super-secret website should appear.

» However, we've only done this from behind the router. The third problem is being able to reach the server from outside our network. For example, from a local bar or diner. Usually, a hostname and IP address are connected though a DNS zone file. Or maybe you use a dynamic DNS service. But we don't want anybody to know about this server, so we can't use either of these solutions. In principle, you can look at your router's WAN IP address, but what if it changes? Here's a slick way to access your server's WAN IP address, even if it's behind a router: `dig +short myip.opendns.com @resolver1.opendns.com`. Try it now on your own Linux machine.

» This command is useful because it can be put into your cron table and executed periodically. Once a day is usually more than enough, as ISPs don't change their IP addresses more frequently than that. Ours changes every few months. You can ssh into your server at any time, run the command, then update the "remote" option in the "client.conf" file if it changes.

» Furthermore, the output can be placed into a file and transferred to another server. For example, `0 */4 * * * dig +short myip.opendns.com @resolver1.opendns.com >> ~/myip.txt; scp ~/myip.txt me@myserver:` is a crontab entry that grabs your IP address every four hours, puts it in a file, then sends the file to another server whose IP address doesn't change—a VPS defined in your SSH config file. This assumes a passwordless SSH key, and that the server is trusted.

» Additional security can be obtained by using GPG to encrypt the file before transmission. Now the file can be put on public servers without your IP address being compromised. For example, the encrypted file can be emailed to you automatically or put into Dropbox. Or indeed, both. However you want to do it, you can now determine the IP address of your router at any time and change the remote option in "/etc/openvpn/client.conf" to point to it.

» When testing at home behind your router, use the 192.168.0.0/16 address assigned to your desktop server. This enables testing with both the server and laptop right in front of you. Once this is working properly, go outside your home (or use a cell phone hotspot), connect to a public Wi-Fi, then test the connection by changing the IP address in the remote option to the WAN IP address obtained from the dig command above. Doing this leads us to problem four: making sure you can access your server when it's behind a router. For routers running DD-WRT, it's easy to set up. Go to the NAT/QoS table and look at the "Port Forwarding" tab. Port 1194 can be forwarded to the server running OpenVPN [Image D].

» You've now set up a super-secret web server that nobody knows about and can't be observed, because of the OpenVPN encryption. Note that this doesn't forward all your Internet traffic to your OpenVPN server—only the traffic between your laptop and the server.

KILLING BAD ACTORS

What happens when someone's not behaving properly, and you want to remove their access to your server? The easy-rsa program enables you to revoke their access. Here's how you do it.

The "/etc/easy-rsa/pki/index.txt" file is the "master database" of all your issued certificates. It will look something like this:

```
R   2710311943242  1809201018282
97913BB18DF2BACC70047EE8E8AF8E29
unknown /CN=bob
V   2710311956532
082F05CAE53FEC2AB52DA56C044C5884
unknown /CN=sally
V   2802062239222  1809201006502
C6DB4B3B0CC7D9EF94DF02E18444FC2B
unknown /CN=joe
```

A `V` indicates a valid certificate, while `R` means that the certificate has been revoked. You can find the common name of the certificates right at the end.

Let's say that we want to remove Joe's access. To revoke his certificate, you would run the following commands:

```
cd /etc/easy-rsa
easyrsa revoke joe
easyrsa gen-crl
```

If you look in "index.txt," you'll find there's an `R` on Joe's line.

The `easyrsa gen-crl` command updates the certificate revocation list located in the "crl.pem" file. Now copy "/etc/easy-rsa/pki/crl.pem" to "/etc/openvpn," add `crl-verify /etc/openvpn/crl.pem` to "/etc/openvpn/server.conf," and restart your OpenVPN server. Remember, OpenVPN is now running as user nobody, so make sure "crl.pem" is world-readable. If you've previously put "crl-verify" into "server.conf," all you need to do is copy over the updated "crl.pem" file.

Predict the Weather with a Raspberry Pi

YOU'LL NEED THIS

RASPBERRY PI
This credit-card sized computer costs around $35.

WEATHER SENSOR
We used the Maker Life kit, but others are available, or you could build your own.

WEATHER, EH? WHO'D HAVE IT? Whether it is the relentless onslaught of that burning gasball in the sky or the incessant gushing of rain, weather never ends—which makes it perfect for a great project, using Linux shenanigans and fancy sensors.

We happened to have a Maker Life Weather Station kit hanging around in the office, which means we're making it (and its Pi Zero W, and included sensors) at least the initial basis of this tutorial. However, you're not missing out if you don't have the same gear to work with. This is something you can put together yourself—various Pi-friendly stores sell sensors that hook on to GPIO pins or sit in USB ports. You could also exploit the more commercial end of the market. The Netatmo Smart Home Weather Station (a slightly painful $180 investment) can be tapped into by WeeWX [**Image A**], which you can find out more about in the "Your Own Weather Website" box (below-right).

So, we now have some sensors, but how these actually work to generate the data we're after isn't important—it's the end result, a stream of data points, that is key. How we interpret that data and what we do with it once we've understood it is what transforms a simple live-reading weather station into a more capable archival machine. It will then give us the opportunity to make predictions based not only on what's happening right now, but also on what happened in the past. –**ALEX COX**

1 PULLING PYTHON AROUND

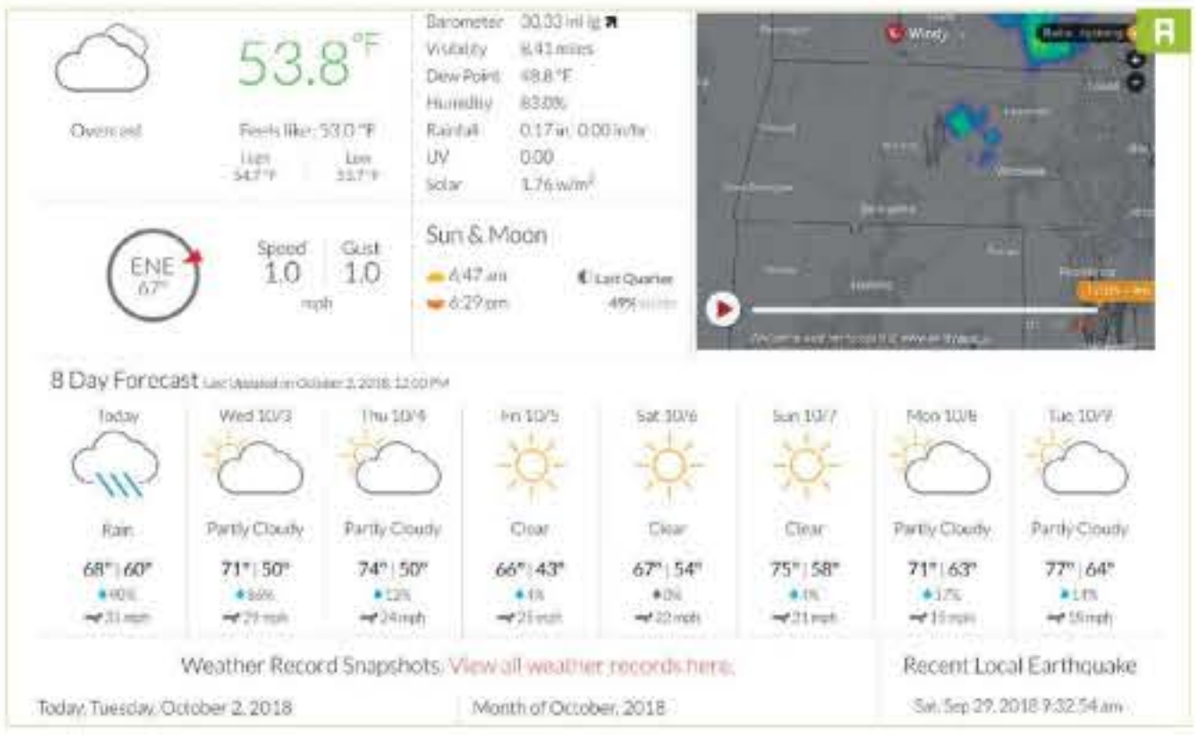
The Maker Life kit (which, it seems, has been discontinued) pulls in its data using a couple of Python libraries. The same is likely true for most Raspberry Pi weather sensors. This is a good thing—Python being the LEGO-esque coding toolkit that it is, it's likely that any sensor you pick up will integrate with any programs you happen to write, as long as you import the appropriate libraries. And this gives us a number of opportunities.

» We could, at the most basic level, pipe this raw output not straight on to the screen, but into a text file, which we can process later to spot trends. This is easy enough: Taking the code obtained by our weather station, we first add a line outside the main loop to open a file in append mode—something along the lines of `f = open("weather.txt", "a")`, then replace any instances where it would print to screen with code such as `f.write("<weather data>")`, with the data being whatever our code had originally pulled out. Be sure to use `f.close()` to cap off the file when you're done with it.

» With more tweaking and a little formatting, you could turn that output into a comma separated file, suitable for importing directly into a spreadsheet and transforming into graphs. Obviously, you need to be a little careful with your storage here, and consider whether you want to write out with such frequency, given that a Raspberry Pi tends to run from a rather fragile SD card.

```
Type "help", "copyright", "credits" or "license" for more information.
>>> import forecastio
>>> api_key = "c3ef6ee3a8d7979cf9733ed5c740e1f9"
>>> lat = -31.967819
>>> lng = 115.87718
>>> forecast = forecastio.load_forecast(api_key, lat, lng)
>>> byHour = forecast.hourly()
>>> print byHour.summary
Breezy starting tonight, continuing until tomorrow morning, and mostly cloudy
starting tomorrow afternoon.
>>> print byHour.icon
wind
>>> print byHour.data
[<forecastio.models.ForecastioDataPoint object at 0x7f650fc27e10>, <forecastio
.models.ForecastioDataPoint object at 0x7f650fc27e50>, <forecastio.models.Fore
castioDataPoint object at 0x7f650fc27e90>, <forecastio.models.ForecastioDataPo
int object at 0x7f650fc27ed0>, <forecastio.models.ForecastioDataPoint object a
t 0x7f650fc27f10>, <forecastio.models.ForecastioDataPoint object at 0x7f650fc2
7f50>, <forecastio.models.ForecastioDataPoint object at 0x7f650fc27f90>, <fore
castio.models.ForecastioDataPoint object at 0x7f650fc27fd0>, <forecastio.model
s.ForecastioDataPoint object at 0x7f650fd3d050>, <forecastio.models.Forecastio
DataPoint object at 0x7f650fd3d090>, <forecastio.models.ForecastioDataPoint ob
ject at 0x7f650fd3d0d0>, <forecastio.models.ForecastioDataPoint object at 0x7f
```

B



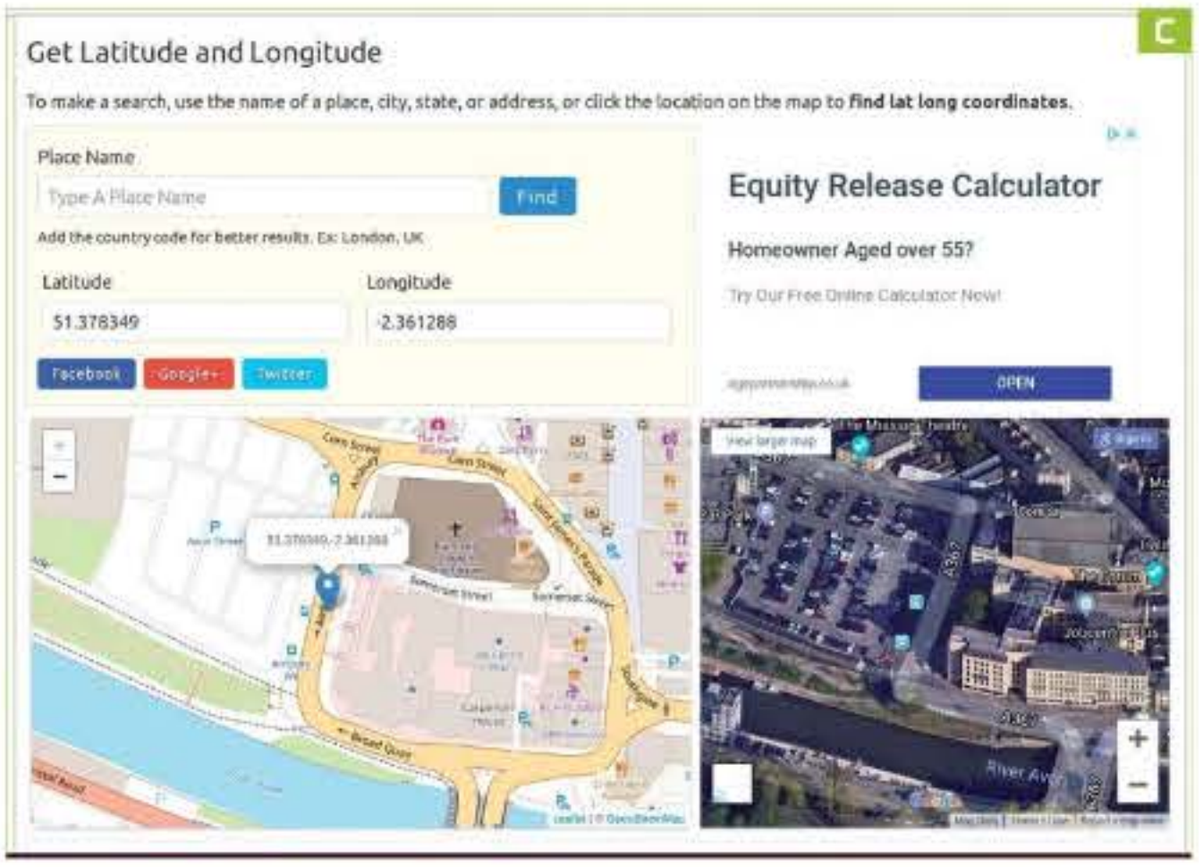
A

2 USING WEATHER LISTS

You could, instead, append that data to a Python list to reduce the number of writes you need to make. Start by creating an empty list variable with `weatherlist = []`. Add a counter variable (you're going to use `i` because, well, that's the done thing) to control both where in that list the data is going to be put, and the frequency that you'll output that data to a file, add one to the counter each time the loop goes through, and switch out your existing `f.write` or `print` statements for `weatherlist.insert(i, <weather data>)` statements, which will build your list as it goes.

» When your counter reaches an appropriate value, use your preferred write method to output the contents of your list to a file. We suggest joining the list items together, dropping it as a single chunk (closing the file by using `with`), then resetting the list and counter:

C


Get Latitude and Longitude
To make a search, use the name of a place, city, state, or address, or click the location on the map to find lat long coordinates.
Place Name
Type A Place Name
Find
Add the country code for better results. Ex: London, UK
Latitude
Longitude
51.378349
-2.361288
Facebook
Google+
Twitter
Equity Release Calculator
Homeowner Aged over 55?
Try Our Free Online Calculator Now!
OPEN

D

```
w_string = ','.join(weatherlist)
weatherlist = []
i = 0

with open('weather.txt', 'a') as f:
  f.write(w_string)
```

» This is very basic, inelegant code. You can, no doubt, do better. Now, we're not casting any aspersions here, but it's fair to say that the sensors that your weather station carries are, unless you've gone a little crazy with the spending, likely not dragging in every single weather metric that matters. Maybe you don't even have any weather station gear, you poor thing. Luckily, we can get modular here, too—both Yahoo (https://pypi.org/project/weather-api) and the excellent DarkSky (https://github.com/ZeevG/python-forecast.io) [Image B] offer up live and localized data, which you can import and process yourself.

3 DARK SKIES ARE FORECAST

Let's look at the latter. Go to https://darksky.net/dev, hit the button, and get yourself an API key, which is required to tap into the data. It's free unless you're a heavy user—you get 1,000 API calls per day, and they're charged at a nominal rate after that. Next, jump into a terminal, and download the relevant wrapper through pip by using:

```
install pip install python-forecastio
```

» Once it's installed, pulling that data in is relatively straightforward. At the beginning of your chunk of Python code, add in the relevant libraries with `import forecastio`, then add some variables just below; `api_key = "<your api key>"` keeps that key (which you'll need to pass to the main function) handy, while `lat = <latitude>` and `lon = <longtitude>` store your precise location, useful for making the most of DarkSky's hyper-local forecasting. If you (somehow!) don't already know your latitude and longtitude, www.latlong.net can connect you to an OpenStreetMap instance that'll cough up the goods [Image C].

» With the prerequisites written in, you can create a forecast object using the following line:

```
forecast = forecastio.load_forecast(api_key, lat, lon)
```

» This puts a whole wedge of data, and the relevant methods to extract it, into the forecast object; pull from it by, for example, adding the following (or a more graceful version of it):

```
weatherHour=forecast.hourly()
print weatherHour.summary
print weatherHour.icon
```

» There are tons more options to exploit, if you're after a particular metric, a particular timescale, or anything else. That forecast object also includes `daily()`, `minutely()`, and `currently()` methods, and you can use `forecast.update()` to refresh the object with the latest info. That raw data is stored in the `data` portion of the DataBlock—do with that what you will.

» If you want to play with DarkSky using a different language, you can—there are wrappers for everything from Python 2 and 3 to Ruby, PHP, and more to be found at https://darksky.net/dev/docs/libraries.

» Finally, if, having read this far, you're now looking for a quick and affordable way to set up your own weather station, devices such as the Flotilla [Image D] (which we wouldn't necessarily leave outside) can get you started for as little as $8. Have fun watching the skies.

YOUR OWN WEATHER WEBSITE

As much as we can play with Python to improve the output of our weather station, there's a lot to be said for at-a-glance personal forecasting. And if you've already dug up a DarkSky key, something such as WeeWX (www.weewx.com) is the perfect tool to get it done. Follow the install guide at www.weewx.com/docs/usersguide.htm to get it installed and started for the first time. Once it's up, you'll be able to access its interface via a local web page.

WeeWX does support a vast number of sensors, although the default list is restricted by the drivers it includes. If it works with your weather gear, that's great; you'll be able to use WeeWX to join in the swarm of user-run weather stations that contributes to WeatherUnderground's vast forecasting network.

However, if you're not using any sensors, you can add the appropriate latitude, longitude, and such into the "weewx.conf" file, and place your API key in the "darksky_secret_key" option to draw the data in directly from there. Make sure WeeWX isn't polling too frequently, lest you raise the ire of the DarkSky API limits. And if you want something prettier, don't miss the Belchertown skin at https://github.com/poblabs/weewx-belchertown.

Surf Securely with a VPN

YOU'LL NEED THIS

WINDSCRIBE
Download the free version of the VPN from https://windscribe.com.

THERE ARE TWO PRIMARY REASONS for wanting to use a VPN. The first is to increase the security of your Internet connection, and the second is to make it appear as though you are located somewhere else in the world. Both of these benefits are due to the fact that when using a VPN, your web traffic is encrypted and routed through secure servers.

A VPN can make it seem as though you are browsing the web from another country by assigning you a foreign IP address—which is great if you want to access, say, the British version of Netflix, or sites that are blocked in your country.

Both free and paid-for VPNs exist, and their quality and reliability can vary wildly. Here we've chosen to take a look at Windscribe, which includes a generous set of features in the free version, but can also be upgraded for a small fee if your needs grow. -MARK WYCIŚLIK-WILSON

1 DOWNLOAD WINDSCRIBE

Point your web browser at https://windscribe.com, and click the "Download Windscribe" button followed by the "Windows" button [Image A]. While you can download Windscribe plugins for your web browser, we're going to look at the Windows program, because it gives you more flexibility than an extension.

2 INSTALL WINDSCRIBE

Once downloaded, double-click the Windscribe.exe file to install it. If a User Account Control dialog appears, click "Yes" to continue. Leave "Express Install (Recommended)" selected, click "Next," wait for the installation to complete, and click "Finish," leaving "Run Windscribe" checked [Image B]. Click "Allow Access" if a Windows Security alert is displayed.

3 CREATE AN ACCOUNT

Because this is the first time you've run Windscribe, you need to create an account. Click "No" if you don't already have one, and you're taken to the sign-up page on the Windscribe website. Choose a username and password, enter your email address, and click the "Create Free Account" button. Click the link in the confirmation email you receive to get started.

4 CHOOSE A COUNTRY

You should find that you are automatically signed in to your account within the Windscribe app—if not, manually enter your username and password. Click the drop-down menu in the center of the program window, and you'll see a list of locations to choose from [Image C]. Because you're using the free version, you have to make a selection from the countries that do not have a star next to them.

5 GETTING CONNECTED

Choose a server in a country you'd like to connect through, and Windscribe tries to connect. As a pop-up message explains, while a connection is being established, you are temporarily cut off from the Internet, so don't switch connections when you're in the middle of something important [Image D]. Another message is displayed when you are connected to the server you specified.

6 QUICK CONNECTION SWITCHING

There is no need to use the main Windscribe program to connect to a server or switch connections. If you find a particular server isn't working as well as you would expect, or you need to switch to another country, you can right-click the Windscribe icon in the system tray. From here, click "Location," followed by the server you would like to connect to instead.

7 CHECK YOUR IP ADDRESS

When you switch to a new server, your IP address changes accordingly. You can keep an eye on the IP address you have currently been assigned in a couple of ways, the first being to simply look in the main Windscribe window. You can also hover your mouse over the Windscribe icon in the system tray, and your IP address is shown in a pop-up window [Image E].

8 AUTOMATIC CONNECTIONS

You'll probably want to make sure that Windscribe runs automatically when you start Windows. In the Windscribe window, click the three-line button on the left, select "Preferences" from the menu, and check the box labeled "Launch on Startup" [Image F]. You can also check "Auto-connect to most recent location" to force the VPN to reconnect to the previously used server after a restart.

9 GET MORE DATA

While the free version of Windscribe gives you a generous 10GB of data to play with each month, you can always upgrade to one of the paid-for monthly subscription options to get more data. However, you can get an extra 5GB per month just by tweeting about Windscribe. Head over to https://windscribe.com/myaccount/tweet4data, and follow the Twitter instructions [Image G].

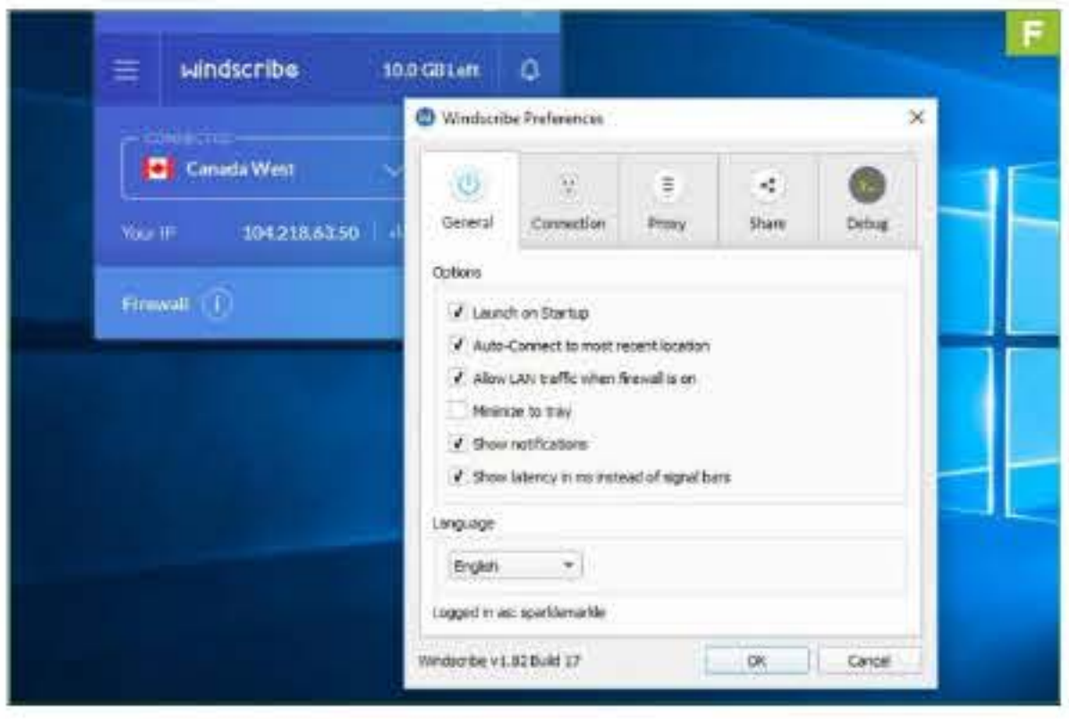
10 GET EVEN MORE DATA!

If 15GB of data isn't enough, and you still don't fancy the idea of a paid-for subscription, there is yet another way to get more free data—by recommending the tool to your friends. Go to https://windscribe.com/referafriend, and you're given a link that you can share with people you know [Image H]. For everyone who signs up using your link, you're given an extra 1GB per month.

A
windscribe
Features
Pricing
Support
Get Started
Log In
Get Started with Windscribe
Chrome
&
Windows

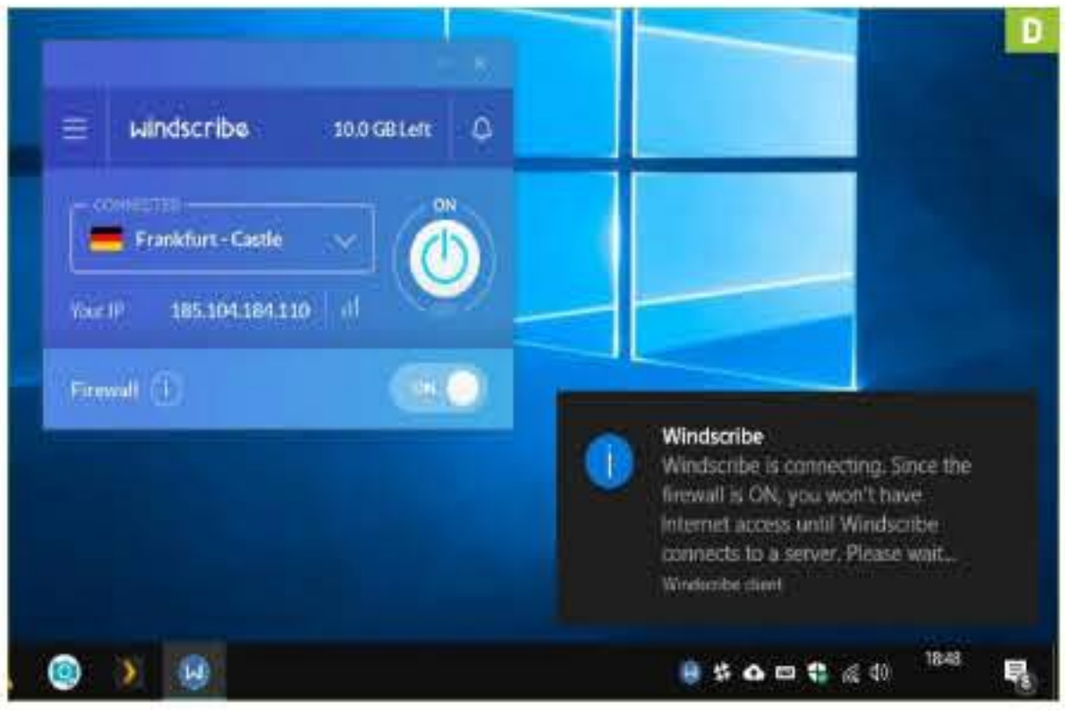
E
windscribe
10.0 GB Left
CONNECTED
Canada West
ON
Your IP
104.218.63.50
Firewall
ON
Recycle Bin
Connected to Canada West
104.218.63.50
11:53

B
Features
Pricing
Support
Setup - Windscribe
windscribe
Completing the Windscribe Setup Wizard
Setup has finished installing Windscribe on your computer. The application may be launched by selecting the installed shortcuts.
Click Finish to exit Setup.
Run Windscribe
Finish


F
windscribe
Canada West
Your IP
104.218.63.50
Firewall
Windscribe Preferences
General
Connection
Proxy
Share
Debug
Options
Launch on Startup
Auto-Connect to most recent location
Allow LAN traffic when firewall is on
Minimize to tray
Show notifications
Show latency in ms instead of signal bars
Language
English
Windscribe v1.82 Build 17
OK
Cancel

C
windscribe
10.0 GB Left
Best Location
Your IP
86.128.215.32
OFF
Firewall
OFF
US West
Los Angeles - Dog
Los Angeles - Dre
Phoenix - Cactus

G
Tweet 4 Data
Want an extra 5GB of free data?
Step 1
Click here to Tweet
Step 2
Enter your Twitter username below


D
windscribe
10.0 GB Left
CONNECTED
Frankfurt - Castle
ON
Your IP
185.104.184.110
Firewall
ON
Windscribe
Windscribe is connecting. Since the firewall is ON, you won't have Internet access until Windscribe connects to a server. Please wait...
Windscribe client
18:48

H
Refer a Friend
Invite friends, earn free data every month, as well as free Pro accounts
How to get started
Give this link to your friends
Rewards

Create a Mosaic Portrait from Photos

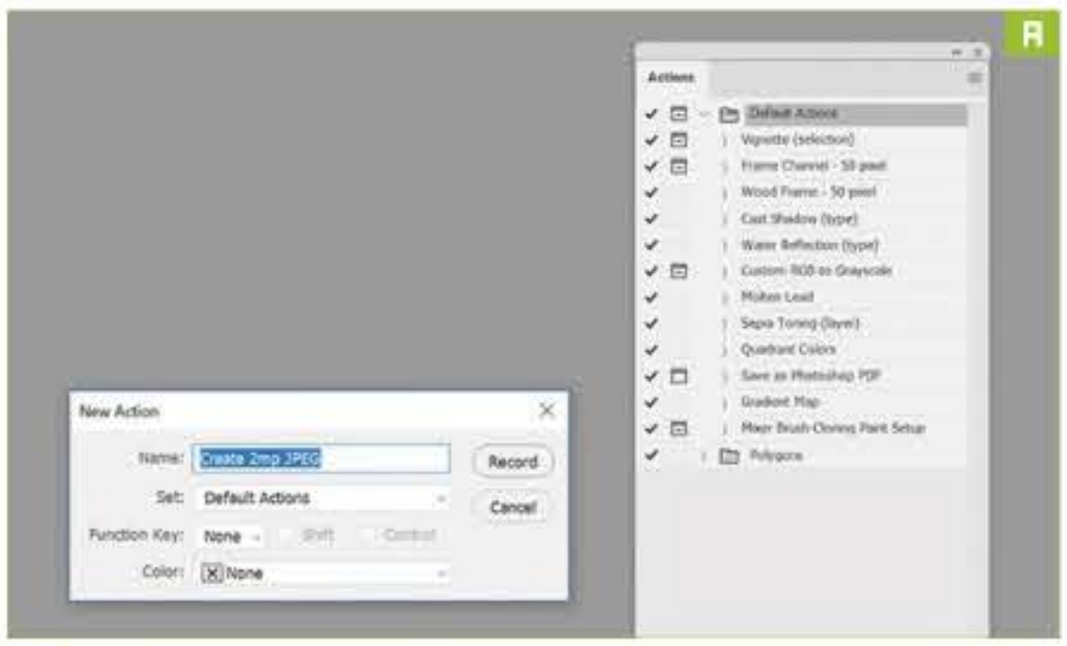
YOU'LL NEED THIS

ADOBE PHOTOSHOP
Subscribe to a suitable package at www.adobe.com.

PHOTOGRAPHS
Lots and lots of them.

THE ROMANS DID A LOT FOR WESTERN CIVILIZATION, but one thing that never made it across the Atlantic was the mosaic. The tradition of creating an image from tiny pieces of stone, each one the kind of picture element that could, perhaps, be called a pixel, can be traced back to a couple of millennia BC in Mesopotamia—the area we would come to know as Iraq. The ancient Greeks and Romans would take the technique to great heights, and it has continued being used across Europe ever since, particularly among the early Christian, Jewish, and Muslim religious traditions, where it was used to portray saints and popes, or intricate geometric patterns.

What if, though, the image wasn't made up of pixels. What if you combined multiple images to create the effect of a larger one? What if there was a software application that could help you with this, and in some cases automate the process? It might be on your hard drive already. Welcome to the world of Photoshop Actions. **–IAN EVENDEN**



1 COLLECT YOUR IMAGES

You need a lot of photos for this, including one to be the "master" photo, so if you've got a folder full of similarly themed images, all the better. A cute use for a mosaic portrait is to use lots of pictures of the subject, or something they're interested in, to create the final result. We happen to have a folder full of pictures of birds of prey—150 in all—so have decided the model in our "master" portrait is an avid birdwatcher. To cut down on processing time, it's a good idea to shrink the source photos beforehand, which is where our first Photoshop Action comes in. Open the "Actions" window ("Window → Actions") and create a new one [**Image A**]. Actions are recorded; you carry out the task you want to automate with the recorder active, and your steps become part of the Action. So, open an image from the source folder, use "Image → Image size" to shrink it to around 2,000 pixels across, and use "File → Save as" to make it into a level 5 JPEG in its own folder. Use the "Stop" button to stop the Action recorder, and if you didn't earlier, give it a sensible name.

2 AUTOMATE

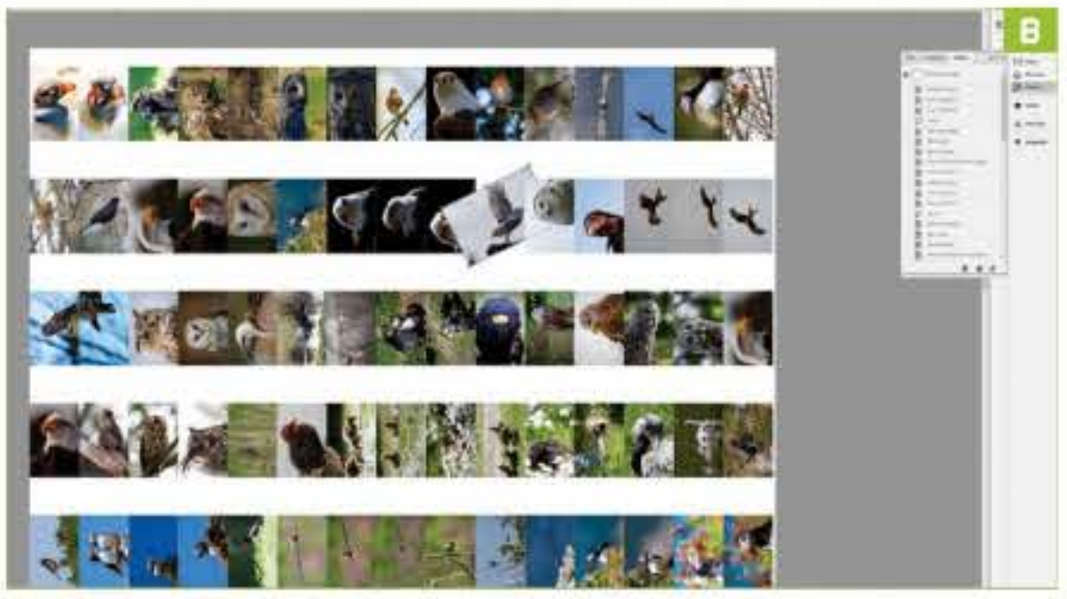
Now you've got your action, you can put it to use. Set it running on a folder, and it churns through every image in it, saving you loads of time. Go to "File → Automate → Batch," and choose your recently created Action from the drop-down. Choose the source and destination folders, and you can specify "Save As" options if you didn't record them in the Action. Check "Override Action Open commands," hit "OK," sit back, and let Photoshop munch through the images.

3 CONTACT SHEET

Once done, you're left with the empty Photoshop interface, but open the folder you marked as the Action's destination, and you'll find it full of small JPEGs. Head back to "File → Automate," but this time choose "Contact Sheet II." Choose the resizing Action's destination folder as your source folder, uncheck "Flatten All Layers," and make the contact sheet's dimensions about the same as the "master" photo you've taken—you may need to close the "Contact Sheet" window to check these. The most important thing is to keep the aspect ratio the same, as you can always alter the pixel dimensions later. If in doubt, err on the side of too big. Work out how many columns and rows you need to get every image on the same document, and put that data in, too. We've checked "Auto Spacing" and "Rotate for Best Fit"—the latter rotates landscape images so they're portrait, creating a smoother effect. Uncheck "Use Filename for Caption." When ready, hit "OK." This takes a long time, and doesn't tell you when it's finished.

4 RESIZE ANY THAT NEED IT

Because we didn't check "Flatten All Layers," every image thumbnail is on its own layer. Select the "Move" tool from the top of the toolbar, and check "Auto-Select Layer" and "Show Transform Controls" on the options bar. Then click every thumbnail that's rotated the wrong way, and use the Transform controls, in conjunction with "Layer → Arrange → Send Backward,"



to resize or rotate it until it looks like the other thumbnails [Image B]. If you've ended up with large gaps between rows, you can drag them closer together, too.

5 CROP TO A PATTERN

Use the "Crop" tool to crop your contact sheet to the size of the mosaic, so there are no white borders. Next, we need to save the mosaic as a pattern. Head to "Edit → Define Pattern." Give it a name—there's one there by default—and hit "OK." The dialog disappears and nothing happens, but that's OK.

6 PATTERN FILL

Open your "master" photo, the subject of your portrait. Mess around with things such as "Levels" and the "Spot Healing Brush," then open the "Layers" palette, and create a new Pattern layer from the same button you'd use to create a new Adjustment layer (a circle with a dark and light half). Immediately, the new pattern you defined earlier appears over the top of your image, hiding it. Change the "Blend Mode" of this new layer to "Overlay," and the subject blends through [Image C].

7 EDIT THE COLORS

Making sure the Background layer is selected, choose "Shadows and Highlights" from "Image → Adjustments." Check "Show More Options," and use the "Amount" sliders in "Shadows" and "Highlights" to adjust the light and dark areas of the image, changing the way the pattern blends with the subject. Experiment with all the sliders.

8 CHANGE SIZE

If you want to change the scale of the pattern, you can—it repeats to fill any gaps. Double-click the left-hand icon on the Pattern Fill layer, and you open the "Pattern Fill" window you saw earlier. Change the "Scale" to make your pattern larger or smaller [Image D]. You can also drag to reposition the pattern, if there's a part you want to fall over a specific area of the subject.

9 FLATTEN AND FINISH

Once happy, save your creation as a PSD to preserve the layers, then use the "Layer" menu to "Flatten" it, and save it as a JPEG for sharing online.

CONTACT PRINTING

A contact sheet comes from the old days of film photography, where negatives would be pressed against a sheet of photographic paper and exposed so that you'd get lines of thumbnails of every image on the film. You get something similar when you place an order with an online digital printer, too. Large format film, many inches along each edge, could be contact printed to provide a useful print, but the small negatives of 35mm film produce contact prints most useful for evaluation purposes.

The same technique was once used to create printed circuit boards. A photoresist—light-sensitive material—is painted on the board, and the "artwork" (the pattern to be etched on to the board) placed alongside and exposed to light, while a solvent is applied to the board. Where the artwork blocks the light, the photoresist blocks the solvent, so the areas exposed to the light are dissolved away, leaving the artwork pattern etched on to the board.

BUILD IT

ZAK STOREY, DEPUTY EDITOR

Ray-Traced Threadripping

Alternatively, you could call this issue's build "How to Make Threads and Alienate People"

LENGTH OF TIME: **1-3 HOURS**

LEVEL OF DIFFICULTY: **EASY**

THE CONCEPT

THE LATTER HALF of this year has seen some seriously cool hardware launches. Whether or not the prices are right, or the technology warrantied, it's hard to deny that compared to the past few years, it's definitely an interesting time to be a tech enthusiast. Whether we're talking about AMD throwing out the rule book when it comes to mainstream core counts, Nvidia dicing with new forms of rendering, taking what are otherwise enterprise grade components and baking them into gaming hardware, or Intel adjusting its own core count and redeveloping its TIM to compensate, compare the last six months to the previous three years, and there's no shortage of things to write home about.

So, what did we decide upon this time around? What's the concept? A modern-day streaming rig, designed to futureproof you for the next couple of years or more. For us, that means two things: a big budget, and a hell of a lot of cores.

There's no doubt that streaming has exploded over the last few years. Those once prestigious "let's play" videos have turned into live streams with incredible audience interaction, and to simultaneously play games, compress and upload that all to Twitch, and run background applications in a timely manner requires a lot of raw processing prowess. It's a money-maker, that's for sure, at least if you're committed, and have the time to do so.

PARTS GALORE

WITH ALL THAT IN MIND, our processor of choice for this was AMD's Threadripper 2950X. Now pitched as the go-to gaming CPU for the high-end budgeteer, this beauty packs 16 cores, 32 threads, a supersized portion of PCIe lanes, and compared to the last-gen 1950X Threadripper, a lot of memory optimizations to make gaming even better in contrast to its Intel counterparts.

That aside, the main aim of our rig is to game at 4K, and as the resolution increases, CPU load decreases. For our GPU, we've gone with the latest Asus GeForce RTX 2080 ROG Strix Gaming OC—what a name, right? It's not at the top of the RTX pile right now, but for $900 it certainly packs a punch, and with DLSS hopefully right around the corner, that investment into those tensor cores could make a huge difference when it comes to the graphics processing leveraged on the antialiasing. With 1080 Ti performance on top of that, it's an ideal combo for any budding streamer, as long as you've got the cash to back it up, and don't mind forking out extra for those shiny new features. If that's not for you, you could just grab a GTX 1080 Ti while they're still hot.

For memory and storage, we've gone for 64GB of G.Skill Trident Z @ 3,200, and a single 1TB Crucial P1 M.2 PCIe SSD. The latter is an incredibly affordable NVMe solution, and although it doesn't have quite the same clout as a 970 Evo when it comes to sequential writes, the reads are very similar, and it's difficult to argue with the price.

The other interesting choices we've gone for are the Be Quiet! Dark Rock Pro TR4 Edition cooler, a super-budget 250W TDP displacing air tower, designed specifically for the big T, and the Silent Base 610 non-windowed, noise-dampened chassis, which comes in at a modest $130.

INGREDIENTS

PART		STREET PRICE
Case	Be Quiet! Silent Base 601 Midi Tower	$130
Motherboard	Asus ROG Zenith Extreme	$470
CPU	AMD Threadripper 2950X	$865
CPU Cooler	Be Quiet! Dark Rock Pro TR4	$90
GPU	Asus GeForce RTX 2080 8GB ROG Strix Gaming OC	$900
Memory	64GB (4x 16GB) G.Skill Trident Z @ 3,200MT/s	$576
PSU	1,200W Corsair HX1200i Platinum	$180
Storage	1TB Crucial P1 M.2 PCIe SSD	$220
OS	Windows 10 64-bit	$100
Total		$3,531

1 THREADRIPPER INSTALLATION

IT'S EASY to forget the hoops you have to jump through to install these Threadripper processors. Take your Torx screwdriver and unlock the three screws located at points 1, 2, and 3 on the socket. Lift up the first bracket (it should pop up, actually), lift the second bracket up with the blue tabs, then slowly slide out the plastic cover. Take your Threadripper processor on its orange sled, and line up the golden corner with the notch on the corner of the socket bracket. Then slowly slide that processor sled down the blue bracket, making sure it locks into place on the latches. Finally, lower the blue bracket back down, followed by the main one, and secure the Torx screws back down in reverse order.

2 COOLER & PASTE

BE QUIET! advises you to install this cooler with the motherboard out of the case. We're not sure that's entirely necessary; it does make installing the fans a little easier, but aside from that, you're solid. The Dark Rock Pro TR4 is incredibly simple to install, and comes with two fans. There are cutouts for memory DIMMs, but it does cover the topmost PCIe slot. That said, do install your memory first. As for thermal paste, we've gone for a light spreading technique. We figured that, given the size of the chip and the location of the four dies, for better consistency in performance, a spread method for Threadripper, as opposed to multiple dots, makes more sense, as it almost guarantees perfect coverage, and minimizes mess. We used an old credit card to carefully spread a thin layer across the entirety of the chip.

3 MOTHERBOARD OVERSIGHT

BY DEFAULT, the X399 Zenith Extreme supports up to three M.2 SSDs directly on the mobo itself, one here (our 1TB Crucial P1), and another two on the M.2 DIMM slot adapter that Asus is implementing. Annoyingly, over the course of our various testing sessions during the second-gen Threadripper period, we've misplaced our adapter, so are limited to just one on this board (this actually scuppered our plans a bit, because we had wanted to use the P1 as additional storage, and a 512GB 970 Pro as our OS device). To install your M.2 here, you simply need to undo the three small screws on top of the chipset cover, and lift it up. Be careful you don't scratch the reflective finish, though.

4 CHASSIS TIME

SO, THE MOTHERBOARD'S mostly done, we've installed the SSD, the memory is in, and the cooler's secured in place, with a nice spread of thermal paste. Now it's time to sort out the chassis. The Silent Base 610 has two buttons on the back that you press to release each side panel, but apart from that, there's little else to do. As standard, the chassis comes with two 140mm Silent Wings 2 fans—we've pulled the one attached to the rear as an exhaust, and are instead using it as an additional intake to promote a filtered positive pressure setup. With this out the way, it's time to install the motherboard. Fortunately for us, the Zenith Extreme comes with a rear I/O shield already installed, so there's no messing around and no risk of forgetting it.

5 RTX MODE ENGAGED

AND SHE'S IN. Say hello to the Asus RTX 2080. Yep, that triple-slot-sized card sits there with its twin eight-pin PCIe power like the beast it is. It's huge, as powerful as a GTX 1080 Ti, and packed with the latest hardware to take on the future of ray-traced games. Probably. As mentioned earlier, this is where we noticed we had to drop the card down a notch to one of the other PCIe slots. Don't worry, though, because thanks to Threadripper's monstrous 64 PCIe 3.0 lanes, each of the reinforced armor slots can run in x16 mode, no sweat. We are slightly concerned about GPU sag, though.

6 CABLE SIMPLICITY

THERE'S SOMETHING COMFORTABLY reassuring about the fact that all of the X399 platform's cables run along the right-hand side of the board. It means we can bunch all the cables we need together, slap a Velcro strap on them, and they're all tidy and out of the way in the back, with the rest of the chassis looking as clean as a whistle. Make sure the front I/O is plugged in, with the relevant pins, your USB header's in place, then slap the side panels back on, and you've got a clean-looking, quiet streaming and workstation build. What's not to love?

1 **The Be Quiet! Dark Rock Pro TR4 features twin 140mm fans, to keep those heat fins dissipating Threadripper's thermal energy.**

2 **Tucked away down here is a special heatsink Asus will send your way if you're using more than a 16-core Threadripper. It's free on request, and helps keep the VRMs cool when dealing with so many cores.**

3 **The RTX 2080 Ti ROG Strix has a triple-slot cooler design, and it's a beast. We'd be lying if we said we weren't concerned about GPU sag.**

4 **These cables may look familiar—they started out life in our Dream Machine 2017 PC. Here, they're hooked up to our beefy HX1200i.**

RED REDEMPTION

THERE IT IS, our 16-core Threadripper rig. We set out to build a relatively affordable streaming machine based around AMD's reshuffling of its Threadripper series. The X series is designed with the pro-gamer in mind, the YouTuber, the Twitch streamer. Its immense clout, alongside improved memory latency and multitasking capability, through multiple application use and pure grunty video rendering performance, makes it an ideal jack of all trades.

The build process was a cakewalk. Installing the CPU, RAM, PCIe SSD, and cooler outside the case first made it particularly easy. Be Quiet!'s Dark Rock Pro TR4 is perhaps the easiest mounting solution we've seen from the German manufacturer. And its beefy stature is enough to keep things ticking over quite nicely—if you're willing to do a bit of tweaking....

Once we started testing, we noticed a few issues. Notably with clock speed. Precision Boost Overdrive, AMD's auto-overclocking feature, varies clock speed depending on temperature. Our system seemed to be trying to hit a 68 C sweet spot. If apps tried to push the processor above that, PBO would throttle the CPU, and performance would degrade (in this case, with successive Cinebench runs). It's less than ideal, and one reason why we ditched it and started looking into overclocking. Aiming for an 80 C maximum (still 20 C lower than TJMax), we started our OC run trying to hit 4.0GHz. Switching the VRMs to a balanced current mode instead of thermal mode lead us into VRM temp issues (even with the Asus VRM heatsink), and the processor throttled itself again. We jumped back into the BIOS, and dropped to 3.9GHz and temperature VRM mode. We left the voltage on Auto, and just played around with the ratio. It's possible you could get 4.0GHz stable, without throttling the VRMs, but 3.9GHz is easily possible.

Gaming performance was ridiculously close to the zero-point. For 4K gaming, CPU upgrades show little benefit. Also, the RTX 2080 performs almost identically to the 1080 Ti. One thing to note: Our ROG Zenith Extreme motherboard did require a BIOS update before we began installing Windows, to make it compatible with the RTX GPUs.

So, we were left with a 16-core, 32-thread 3.9GHz machine, with 64GB of DDR4 clocking in at 3,200MT/s, a 1TB Crucial P1 M.2 PCIe SSD, and a nice quiet rig, operating at 70 C. Pretty good in our eyes. Although the price is a bit much, it's only $130 more than our test bench was originally specced at.

BENCHMARKS

	ZERO-POINT	
Cinebench R15 Multi-Thread	2,178	3,396 (56%)
CrystalDisk QD32 Sequential Read (MB/s)	3,136	1,950 (-38%)
CrystalDisk QD32 Sequential Write (MB/s)	2,126	1,984 (-7%)
Rise of the Tomb Raider (fps)	68	66 (-3%)
Total War: Warhammer II (fps)	42	42 (0%)
Tom Clancy's Ghost Recon Wildlands (fps)	38	38 (0%)
3DMark: Fire Strike (Index)	6,988	6,690 (-4%)

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Our zero-point consists of an Intel Core i9-7900X, 32GB of G.Skill Ripjaws V @ 3,000, an MSI GeForce GTX 1080 Ti Gaming X, and a 512GB Samsung 960 Pro M.2 PCIe SSD. All tests were performed at 4K at the highest graphical profile.

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REVIEWS

TESTED. REVIEWED. VERDICTIZED.

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AMD Threadripper 2970WX

Breaking down barriers

AFTER SMASHING a personal target in a Cinebench overclocking push, it's hard to ignore the sensation of victory hovering overhead. Over 5,000 points in Cinebench, competitive gaming scores, low idle power draw, x264 over the 81fps mark—it's all there. A kick-ass processor, and we haven't even stepped out of the opening paragraph.

That said, the 2970WX isn't for the faint of heart, and it's not aimed at gamers either. It's a finely honed tool, tempered to maximize your efficiency in any and all workloads. There are 24 cores thumping away at the heart of this chip, six per CPU die, each die communicating with one another to break up those application processes across the 48 threads. Those zeros and ones are catered for by a huge 78.25MB of cache (64MB of L3, 12MB of L2, 2.25MB of I-Cache). On top of all of that, there's still support for quad-channel memory, 64 PCIe lanes, and all the features that the mainstream Threadripper series has had for the last year or more (we're talking precision boost, and all the software tweaks you can muster through SenseMi). Oh, and at stock, it's cool. Seriously cool. We're talking maximum load temps of 50 C, under a 240mm AIO.

But before all that, let's talk about memory. Basically, only two of the dies have direct access to the memory channels, each one having two. The other two dies have to send and receive their memory requests through those first two dies directly, in a sort of piggyback mode. In short, you can expect memory latency all the way up above 100ms per request—not a problem for professional workloads, but not good for gaming. With two lanes going into two dies, and there being four lanes total, the obvious question is: Why not redesign the chip so that one memory channel comes from each die? The reason for that is bandwidth. Split the channels up, and you cut the bandwidth in half for those two main dies, reducing performance significantly. Then why no octo-channel memory instead? Well, that would mean a new socket, and new motherboards.

How great an effect does this have, then? Well, overall, it really does depend on which game you're testing. Across our suite, only *Total War: Warhammer II* suffered because of the memory allocation mode, with frames dropping by half. It's very much a case by case scenario. Switch to game mode, however, and AMD's RyzenMaster drops to local mode memory only, with *Total War's* performance sitting where we would expect. That's a bit annoying, because it does require a full system restart, but in today's age of superfast SSDs, it's just that—an annoyance at most.

Computational performance, though, is nothing short of spectacular. Over 4,400 points in Cinebench, 172 in single-core mode, x264 above 80fps, and load temps of 50 C make this a killer production part. We've gone for a thin spread of paste across the entire IHS on this one, similar to our "Build It," and that seems to work best. As for overclocking, cranking the voltage up to 1.43V was enough to grab 4.15GHz across all 24 cores. With temps sitting happily around the 75 C mark, we managed over 5,000 points in Cinebench R15. The irony is it took five consecutive attempts to get that figure, each one quicker than the last, as the 2970WX completes the run so fast, the cores don't have enough time to hit max load before they've completed the test. Keeping CPU utilization high through successive runs was the only solution—a rolling start.

Is this CPU for you, then? Well, it depends on what you want. For the price, it's an incredible feat of engineering brilliance. If CAD/CAM, 3D design, or rendering is your game, those 24 cores are simply awe-inspiring. If you're solely after a gaming chip, though, the 2950X is both better value for money, and less annoying overall in games that need that local memory mode. **–ZAK STOREY**

BENCHMARKS

	AMD Threadripper 2970WX	Intel Core i9-7980XE
Cinebench R15 Single (Index)	172	**186**
Cinebench R15 Multi (Index)	**4,407**	3,329
Tech ARP's X264 (Avg fps)	**81.04**	52.65
Fry Render (m:s)	1:20	**1:04**
AIDA64 Memory Latency (ns)	**68**	88
AIDA64 Memory Bandwidth (MB/s)	**75,967**	74,971
Power Draw Idle/Load (Watts)	84/324	**66/258**
Total War: Warhammer II @ 1080p (fps)	74	**82**
Ghost Recon Wildlands (fps)	57	**61**
Middle Earth: Shadow of War (fps)	92	**95**
3DMark Fire Strike (Index)	15,476	**18,351**
Maximum Overclock @ Voltage (GHz @ V)	4.1 @ 1.43	4.4 @ Auto
Price to Performance (Index)	**3.39**	1.62

Best scores are in bold. Our test bed consists of an Asus ROG Zenith Extreme, an Asus X299 Prime-Deluxe, 32GB (4x 8GB) of Corsair Dominator Platinum, and an Nvidia GeForce GTX 1080. All games were tested at 1080p on the highest graphical profile, with average fps noted.

VERDICT **9** KICK ASS!

AMD Threadripper 2970WX

+ TIME & SPACE RIPPER Incredible multicore performance; strong single-core; low temps; good price.

– LATENCY RIPPER Some games might require game mode.

$1,300, www.amd.com

SPECIFICATIONS

Base/Turbo Clock	3GHz/4.2GHz
Cores/Threads	24/48
Lithography	12nm
Cache	L3 64MB
Memory Support	128GB DDR4
Memory Channels	4
Max PCIe Lanes	64
TDP	250W

Few words can
truly describe the
powerhouse properties
of this part.

Nvidia GeForce RTX 2070 Founders Edition

More of a side-step shuffle than a leap forward

WE'VE BEEN SPOILED by the past several generations of Nvidia graphics cards, particularly with the GTX 970 and GTX 1070. The 970 was faster than the previous generation, and even came close to the Titan Black, with a price of only $330. The 1070 proclaimed superior performance to every prior card, including the Maxwell Titan X, with a starting price of $380. Those were good times. The RTX 2070, and the Founders Edition in particular, make us long for the days of previous Nvidia GPU advances.

To be fair, the RTX 2070 packs a lot of new technology into its beefy package. The TU106 chip is only slightly smaller than the GP102 in the 1080 Ti, and includes the new Tensor and RT cores, which help to accelerate machine learning and ray-tracing calculations. But as with the other Turing GPUs, we're still waiting for the games to arrive. Nvidia has a list of 25 games slated to support DLSS, and 11 games with ray-tracing support. Several of those are already available, but as we go to print, the patches to enable DLSS and/or ray tracing still haven't arrived.

It's difficult to say precisely how any of the RTX family of cards perform with ray tracing or DLSS. We've done some preliminary testing using Nvidia-provided demos, and if the results hold for actual games, DLSS could boost performance by about 40 percent over TAA, thanks to rendering at half the resolution, and using an AI-enhanced upscaling and antialiasing algorithm. Comparing image quality, in motion it's difficult to spot the difference between 4K DLSS and 4K TAA, though comparing screenshots, there's clearly some compromise—some aspects look better with DLSS, others look better with TAA. Still, it's a net win, and the RTX 2070 with DLSS even outperforms a GTX 1080 Ti with TAA. But it's apples versus oranges.

Ray tracing shows even greater gains, with the *Star Wars* elevator demo running more than three times as fast on the RTX 2070 compared to the GTX 1080 Ti. The catch is that we're talking about 35fps on the 2070 compared to 10fps on the 1080 Ti, at 1440p. Three times as fast in ray-tracing performance sounds great, but given the choice between traditional rasterization techniques at 60–100fps or ray tracing at 30–40fps, most gamers will take higher frame rates.

Even with all the new features in Turing, it's first-gen hardware. By the time ray-

A well-built dual-fan solution, which at nine inches long, can fit into smaller cases.

tracing support in games really starts to gain traction, we may have second or even third-generation hardware that makes the current RTX cards look pitiful. And it's not like games are going to switch to ray tracing only any time soon, because all previous graphics cards can't reasonably support the technology. That leaves us with RTX 2070 performance that only just edges past the GTX 1080.

Kudos to Nvidia for pushing into new frontiers with the Turing architecture, because someone had to do it. If you're looking to build a new PC or upgrade from a graphics card that's a couple of generations old, the RTX 2070 isn't a bad option, especially if you skip the Founders Edition, and go for a reference model, such as EVGA's 2070 Black. You lose the factory overclock, but we easily made up for that with manual overclocking, adding 150MHz on the core and 500MHz (15GT/s effective) on the GDDR6.

The RTX 2070 is arguably the best $599 graphics card available right now, especially with the GTX 1080 and 1080 Ti being phased out. But if you already own a GTX 1070 or faster, we'd skip the 2070, and hold off for the inevitable second-gen RTX cards. The first generation isn't terrible, but it's definitely underwhelming and expensive. **–JARRED WALTON**

VERDICT **7**

Nvidia GeForce RTX 2070 Founders Edition

+ FROGGER Beats GTX 1080; features for the future; sturdy and compact design.

– ROADKILL Slower than the 1080 Ti; waiting for RT and DLSS games; generational pricing.

$599, www.nvidia.com

GPU BENCHMARKS

	Nvidia GeForce RTX 2070 FE	Nvidia GeForce GTX 1080
Middle Earth: Shadow of War (Avg fps)	**73/40**	61/35
Total War: Warhammer II (Avg fps)	**84/48**	73/40
The Witcher 3 (Avg fps)	**78/44**	68/39
Rise of the Tomb Raider (Avg fps)	**63/35**	62/33
Wolfenstein II (Avg fps)	**149/81**	120/68
Price to Performance ($ per fps)	5.88	**4.55**

Best scores in bold. One-off benchmarks. Our test bed consists of an Intel Core i7-8700K, 16GB of G.Skill DDR4-3200, an MSI Z370 Gaming Pro Carbon, and a 500GB Samsung 970 Evo. All games tested at highest graphical profiles, with AA turned up at 1440p and 4K.

SPECIFICATIONS

GPU	Turing TU106
Lithography	TSMC 12nm FinFET
Transistor Count	10.8 billion
CUDA Cores	2,304
Texture Units	144
ROPs	64
Core/Boost Clock	1,410/1,710MHz
Memory Capacity & Type	8GB GDDR6
Memory Speed	14GT/s
Memory Bus	256-bit
TDP	185W
Display Connectors	DisplayPort, HDMI, USB Type C, DVI-DL

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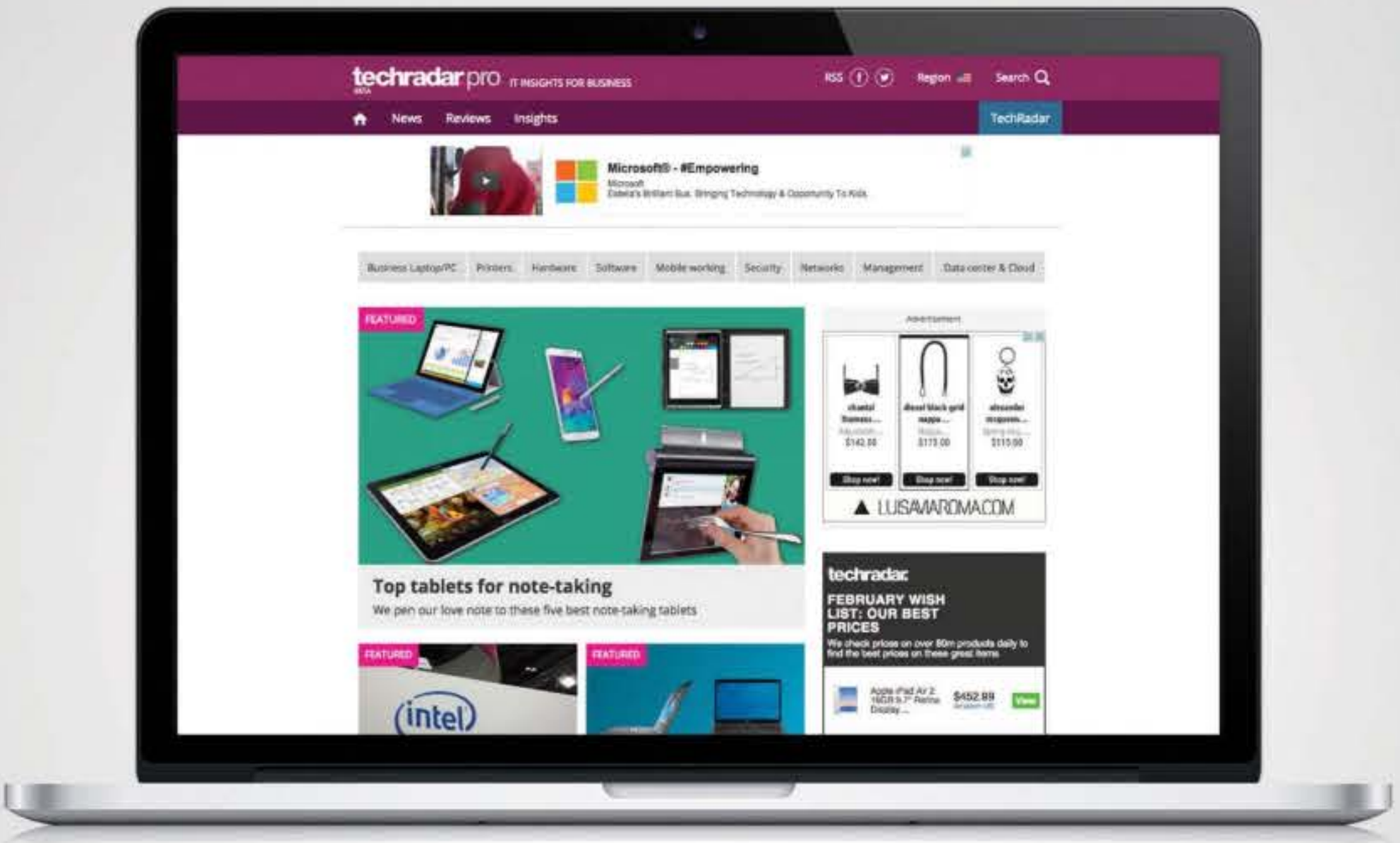
IT INSIGHTS FOR BUSINESS



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Asus ROG Strix RTX 2080 Ti OC

Kicking maximum 4K butt

THE BELLIGERENT TIRADES against Nvidia's mad marketing ploys have to end. The company's been plagued with everything from increased failure rates to a torrent of abuse from journos. And with good reason. The insane price jump and repositioning of the brand, in conjunction with a lack of a significant performance increase, was a bitter pill to swallow, all in the name of ray tracing and DLSS antialiasing, which we've still yet to see.

But we can only rail against the company for so long. Despite it all, Nvidia is still very much king of the hill when it comes to graphical performance. There is no competition at the high end at all. Vega is a flop in comparison to the GTX 1080. And this? This card is pure power.

Let's forget about the price for a minute, and take a look at the pure performance numbers across our test suite. Average frame rates at 4K: *Shadow of War*, 74fps; *Warhammer II*, 58fps; *Rise of the Tomb Raider*, 87fps; *Ghost Recon Wildlands*, 48fps. Those are some serious numbers to push at the super-high-end. Arguably, for the first time ever, that sweet spot has been hit. There's no compromise here at all.

If you want to game at 4K (and trust us, you do), this card will happily take any AAA title you can throw at it, and pump out an incredibly enjoyable, super-smooth experience, no sweat. And that in itself is pretty dishy. Asus's Strix RTX OC variant also comes packing a ridiculously oversized triple-slot cooler (or 2.7-slot, according to Asus). A real beast of a thing, and absolutely worth the extra cash. It's unbelievably quiet, even under load. This is thanks to a combination of intelligent fan design (called Axial fan tech), a stupendous six heatpipes in total, and a truck-load of fins. None of the RTX cards we've seen so far have been small affairs, but this one takes the cake.

That $1,350 price point, though—oof, that's a biggy. However, our grudge stems less from the cost, and more from what the card (or the GPU in this case) is called. Typically, when a new series of Nvidia cards is launched, it follows an almost identical pattern. The first month we see a GTX X80 launch, followed quickly by an X70, then a Titan of some description. The X80 is usually $600–700 or so, the X70 $400–500, and the Titan comes in at an expected $1,000–1,200 price point. About 10 months later, a big one drops, usually in response to AMD—the X80 Ti. This is usually a cut-down variant of the Titan we saw at launch, but with a touch less memory, some of the features turned off, and a better binned chip. Yet what's most important about its launch is that it usually arrives at the same price as the X80 originally retailed for, shuffling the market down by $100–200 a go. This makes the entire range more competitive, and even better value. However, with the 2080 Ti arriving on launch at the price of a Titan, the likelihood of us seeing that happen this generation is slim to none.

On the whole, Asus's RTX 2080 Ti OC is a fantastic card. Its incredible performance at 4K makes it the true king of the resolution, and brings down that 60fps 4K Ultra barrier. The card looks good despite its girth, the RGB isn't too intimidating, and thanks to aiming for that 75 C temperature mark, the fans are excessively quiet. We just wish the price was lower. A lot lower. **–ZAK STOREY**

VERDICT **8**

Asus ROG Strix RTX 2080 Ti OC Gaming

RAGNAR Incredible 4K performance; super-quiet; good aesthetics.

ROLLO Still no sign of DLSS or ray tracing; pricing is nuts; high power draw.

$1,350, www.asus.com

BENCHMARKS

	Asus ROG Strix RTX 2080 Ti OC Gaming	Zotac GeForce RTX 2080 AMP
Middle Earth: Shadow of War (Avg fps)	**119/74**	96/58
Total War: Warhammer II (Avg fps)	**102/58**	79/44
Tom Clancy's Ghost Recon Wildlands (Avg fps)	**74/75**	63/40
Rise of the Tomb Raider (Avg fps)	**145/87**	121/66
Power Draw Idle/Load (Watts)	77/419	**76/390**
3DMark Fire Strike Ultra (Index)	**8,332**	6,713
Price to Performance ($ per fps)	13.00	**9.58**

Best scores in bold. Our test bed consists of Intel Core i7-8700K, 16GB G.Skill DDR4-3200, MSI Z370 Gaming Pro Carbon, and 500GB Samsung 960 Evo M.2. Games tested at highest graphical profile, AA turned up, @ 1440p/4K.

SPECIFICATIONS

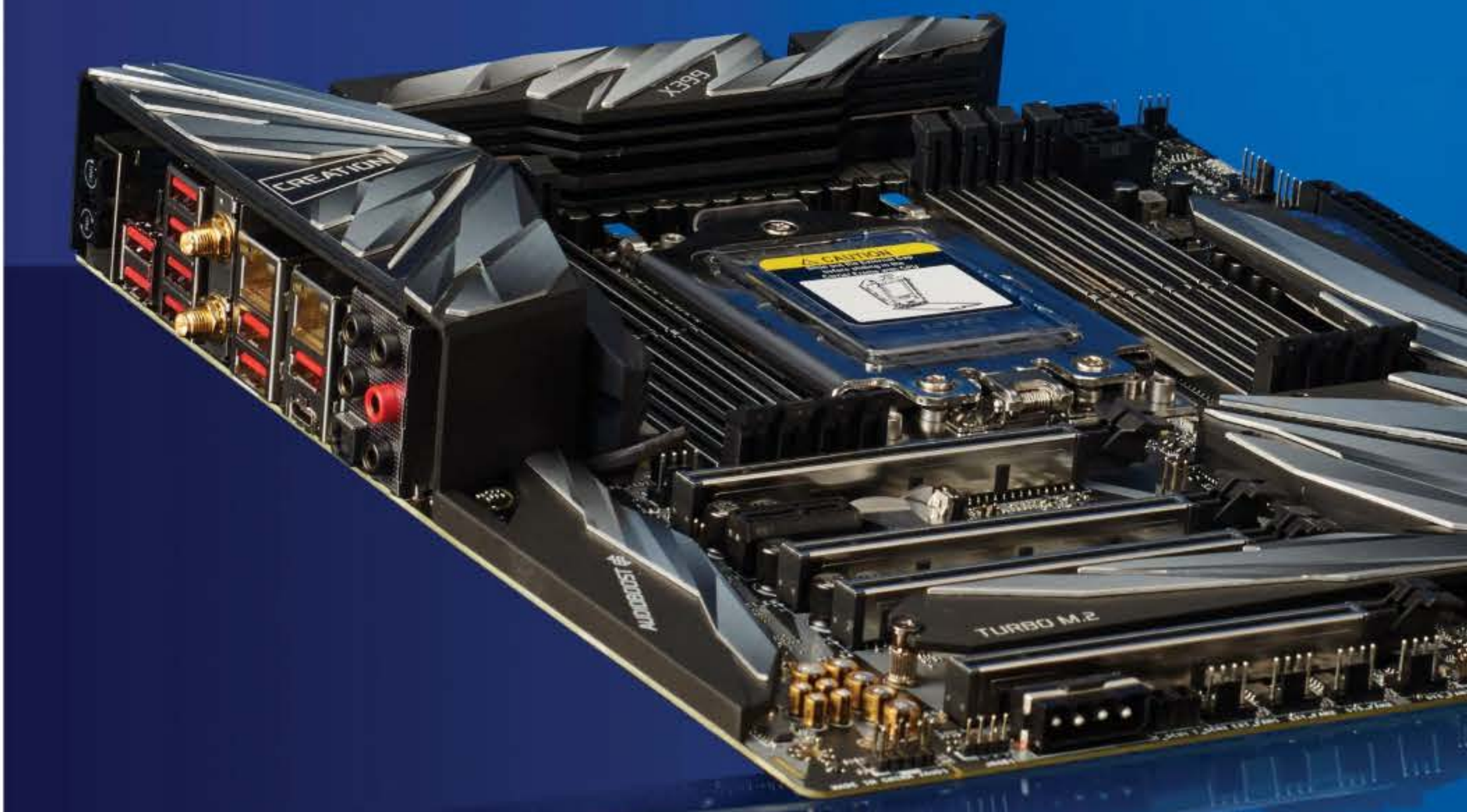
GPU	TU102
Lithography	TSMC 12nm FinFET
Transistor Count	18.6 billion
CUDA Cores	4,352
Texture Units	272
ROPs	88
Core/Boost Clock	1,350/1,665MHz
Memory Capacity & Type	11GB GDDR6
Memory Speed	14GT/s
Memory Bus	352-bit
TDP	265W
Display Connectors	2x DisplayPort, 1x HDMI, 1x USB Type C

MSI MEG X399 Creation

A full-fat super-solution for Threadripper

HOT DIGGITY, is this board something else! From the extravagant styling, to the power phase design, the RGB LEDs, and the expansive connectivity, this mobo has it all. It's a beast, and in our eyes, MSI has created something truly remarkable.

Threadripper's always been an odd one when it comes to motherboards; it benefits massively from improved power delivery systems. As most of the I/O navigates its way directly to the processor itself, as opposed to going through a chipset, connectivity has usually been a bit of an afterthought, so the premium boards are typically less about "What can you plug in?" and more "How well does it handle current?" Back in the early days of 12 and 16-core processors, that was particularly evident when overclocking, especially as the VRMs began to take



more of a grunt—having to deal with those 180W TDP generating volts, heat was a potential issue. Today, with 24 and 32 cores, you need a lot more juice, which in turn means better power delivery, and thermals to take into account. Just take a look at the ROG Zenith Extreme from Asus, a flagship motherboard, now being offered with a free heatsink upgrade to make sure your 24-core-plus parts don't throttle under load. You get the picture. The 24-core zone is tough stuff.

So, what makes the MEG X399 Creation so special, apart from its absolutely bonkers looks? A 19-phase power delivery design adorns the top of the board, covered by an impressive chunk of aluminum. Compare that to Asus's 8+3 design in the Zenith, and you'll start to see why the differences occur when push comes to shove under load—this board kicks some serious butt.

Speaking of which, let's talk numbers. For our testing (and because we haven't reviewed many X399 boards), we used the Threadripper 2950X. This 16-core, 32-thread giant is, admittedly, more focused on the gaming scene than on professional workstations, but it should still show us just what this board can do under pressure. So, we saw X264 at 68.51fps (versus the Rampage's 64), Cinebench R15 clocked in at 3,259, versus 3,225, and Fry Render came in at 1:20, versus 1:24. Not huge margins, but what was impressive was the power draw figures. Under load, the MEG drew 299W from the wall at its peak. Compare that to the Asus's 366W, and you can see the difference (and perhaps restraint in applying voltage) that MSI is leveraging.

When it comes to overclocking, the MEG continues to pull ahead of its rival. In our undervolting test, the MEG managed to hold a 4.0GHz overclock across all 16 cores, with a meager 1.135V pumped into the CPU, versus the Zenith Extreme's 1.15. It certainly has some overclocking chops, that's for sure. If nothing else, it also shows you how cautious AMD, Asus, and MSI have been when applying their stock auto voltages. Usually, you can expect voltages to spike anywhere from 1.25V to 1.35V under load, with load temps of around 60 C when using a 240mm AIO. Drop that down to 1.15V or 1.175V, and you'll see those temps plummet by around 10–15 C overall.

So, the MSI MEG performs well, looks absolutely insane, has more than enough rear I/O and internal connectivity, costs the same as the Asus ROG Zenith, and will save you money on your electricity bill as well. There must be a catch. Well, compared to the Zenith, it does lack an OLED display, and it doesn't have the integrated DIMM M.2 support that the Asus mobo does. But, honestly, that's about it. For the money, MSI has produced a fantastic motherboard here, which would sit proud and true in any high-end Threadripper system. -ZAK STOREY

VERDICT 9 KICK ASS!

MSI MEG X399 Creation

+ POLYGONS Impressive design; good VRM solution; great performance; strong power draw; good connectivity.

– ETCH-A-SKETCH BIOS still tricky to navigate; no integrated backplate.

$550, www.msi.com

SPECIFICATIONS

Chipset/Socket	X399/sTR4
Form Factor	E-ATX
Memory Support	128GB quad-channel DDR4 @ 3,600MT/s
M.2/U.2 Support	3x M.2
SATA Support	8x SATA 6Gb/s
Max PCIe Support	4x PCIe x16 (x16x16x16x16)
Rear I/O	9x USB 3.1 Type A, 1x USB 3.1 Type C, wireless A/C, dual Gigabit Ethernet, 5.1 audio, optical audio out, CMOS reset, BIOS reset

MOTHERBOARD BENCHMARKS

	MSI MEG X399 Creation	Asus ROG Zenith Extreme
TechARP's X264 (Avg fps)	**68.51**	64.07
Cinebench R15 Multi (Index)	**3,259**	3,225
Fry Render (m:s)	**01:20**	01:24
AIDA64 Memory Latency (ns)	89.6	**67.9**
CrystalDisk QD32 Sequential Read (MB/s)	**1,857**	1,822
CrystalDisk QD32 Sequential Write (MB/s)	1,695	**1,706**
Power Draw Idle/Load (Watts)	70/**299**	**69**/366
Total War: Warhammer II (Avg fps)	**76**	**76**
Lowest Voltage @ 4.0GHz (Volts)	**1.125**	1.15
Maximum OC Achieved (GHz)	**4.2**	**4.2**

Best scores are in bold. Our test bed consists of an AMD Threadripper 2950X, 32GB of Corsair Dominator Platinum DDR4 @ 3,000MT/s, an Nvidia GeForce GTX 1080, and a 1TB Crucial P1 M.2 PCIe SSD. *Total War: Warhammer II* was tested at 1080p, on the Ultra preset.

MSI certainly hasn't held back on ostentatious design elements here.

Intel Optane SSD 905p 1.5TB

Intel ups Optane's ante once again

DÉJÀ VU ALL OVER AGAIN? Yup, it's another Optane drive from Intel. It's an intriguing contradiction that Optane has us at one and the same time wondering how on earth the company can put out yet another spin on its Optane product line so soon, and also considering whether, with this particular drive, Optane is finally going to absolutely, unambiguously deliver on its immense hypothetical promise.

Optane drives, of course, are based on Intel's 3D Xpoint tech. We've covered its technological underpinnings before ad infinitum, and in some detail. Suffice to say for now that the basic idea is a brand new type of non-volatile memory that seemingly has it all. More sheer speed than conventional NAND flash memory. Lower latency. Even greater endurance.

The numbers Intel originally claimed were spectacular. 3D Xpoint wasn't just a bit better than flash memory, it was orders of magnitude superior. Then the first Optane-branded products based on 3D Xpoint arrived, and there wasn't a great deal of rejoicing. They were expensive and offered patchy performance at best. But that was early 2017, and the arrival of those initial M.2 Optane cache drives. Since then, we've had the high-end DC P4800X PCI Express card drive, the 900p flagship consumer card, the more mainstream 800p M.2 drives, and a refreshed cache drive.

Enter, therefore, the Intel Optane 905p. As the name suggests, it's a refresh of the 900p premium consumer product. That makes it either a second or third-generation 3D Xpoint technology implementation, depending on how you look at it. Whatever, as the tech matures, expectations harden. A little leeway is inevitable for a radical new technology, but Optane has been around long enough that we'd like to be able to say it's just darned fast, as opposed to pointing your attention at the low latency and hope you don't notice the patchy bandwidth. The problem, of course, is that the underlying 3D Xpoint chips remain first generation.

READ UP

But never mind, what's new with the 905p? It's been around for a few months in 480GB and 960GB variants, but this huge 1.5TB version is very much the latest thing. Broadly, it's a refinement of the existing 900p series, rather than a radical departure. There's a moderately revised seven-channel controller and firmware, still of Intel's own making, and the speeds and feeds are slightly up on the 900p. So, reads are now claimed to peak at 2.6GB/s, with writes at 2.2GB/s. Similarly, the IOPS ratings have crept up to 575K and 500K respectively for reads and writes.

The very latest flash drives can match or beat all those numbers, of course, and sometimes by a large margin. Samsung's 970 Pro is good for up to 3.5TB/s of sequential reads. Anyway, by the numbers, the new 1.5TB 905p performs pretty much in line with expectations when it comes to sequential throughput, which means it's fast, but not electrifying.

Of more interest are the 4K numbers. Here the 905p puts in an extremely strong 4K read performance of 123MB/s. That's roughly twice as fast as the Samsung 970 Pro. On the other hand, the Samsung is about 70 percent faster for 4K writes. In our real-world internal file copy test, it's neck and neck, with both doing it in 29 seconds, which works out at slightly over 1GB/s of throughput. Impressively, the 905p will keep that rate up seeming indefinitely. We filled the drive up prior to testing, and it maintained that performance for all 1.5TB.

You could argue that simple sequential tests don't give much insight into real-world performance. In that scenario, the 905p's neatly symmetrical 4K performance and internal file copy endurance show its true real-world strengths. Random read performance is particularly important to the end user experience, and it's where the 905p is strongest. So, the numbers still aren't all there, but, subjectively, there probably isn't a drive that will make your PC feel faster than the 905p. **–JEREMY LAIRD**

PROCESSOR BENCHMARKS

	Intel Optane SSD 905P 1.5TB	Samsung 970 Pro 512GB	Intel SSD DC P4510 1TB
30GB Internal Copy (Seconds)	**29**	**29**	32
Atto Sequential Read (MB/s)	2,640	**3,561**	3,158
Atto Sequential Write (MB/s)	2,320	**2,385**	2,059
CrystalDiskMark Sequential Read (MB/s)	2,345	**3,112**	1,431
CrystalDiskMark Sequential Write (MB/s)	2,096	**2,338**	2,032
CrystalDiskMark 4K Read (MB/s)	**123**	66	35
CrystalDiskMark 4K Write (MB/s)	135	**231**	207

Best scores are in bold. Our test bench consists of an Intel Core i7-8700K, an Asus Maximus X Hero, an Nvidia GeForce GTX 1080, 16GB of Corsair Dominator Platinum DDR4, and a Samsung 850 Evo 250GB OS SSD.

VERDICT **8**

Intel Optane SSD 905P 1.5TB

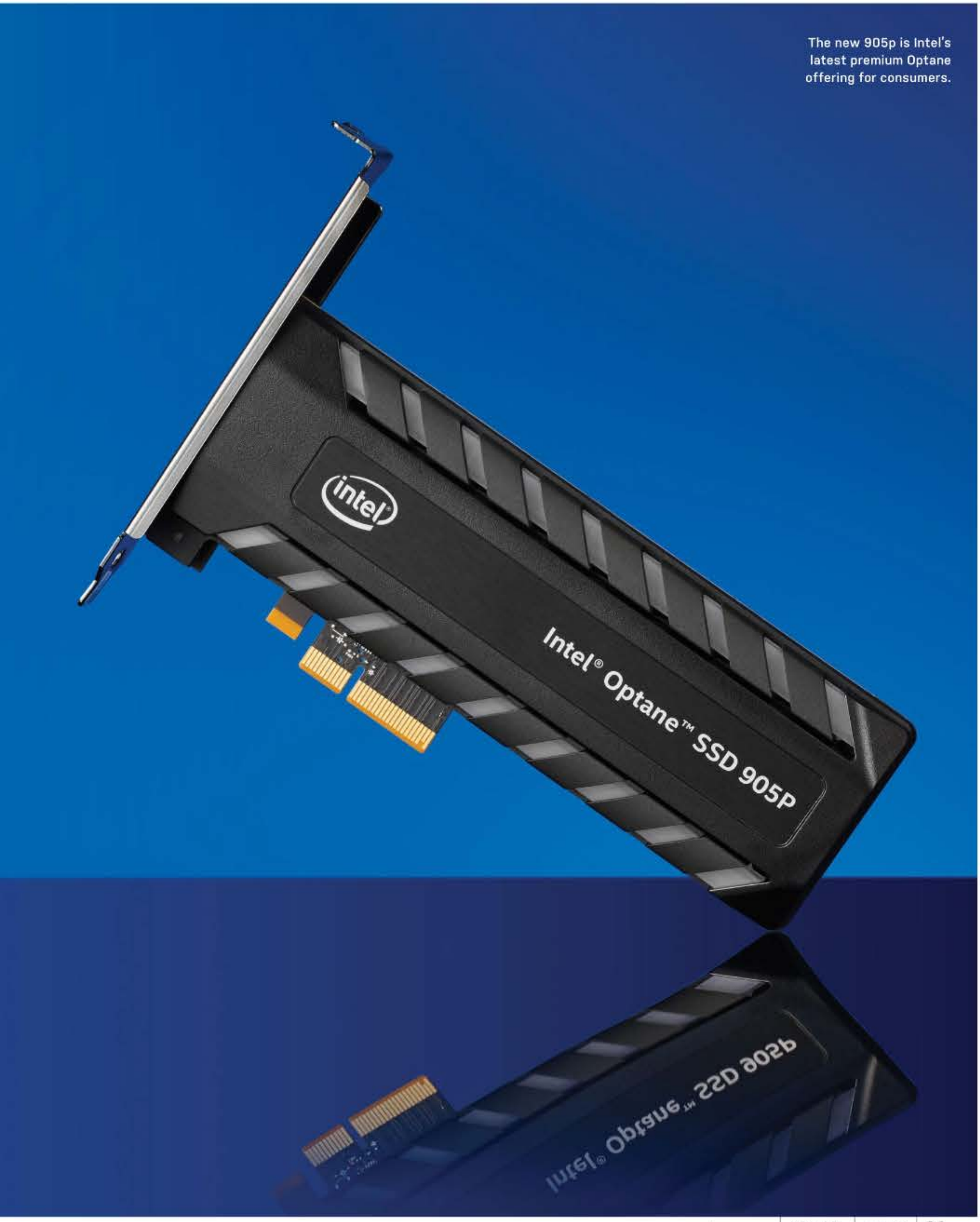
HIGH OCTANE Super-performance where it subjectively counts; big endurance advantage over flash drives.

HIGH JINKS Punitively priced; outpaced by NAND flash drives by some measures.

$2,097, www.intel.com

SPECIFICATIONS

Capacity	1.5TB
Interface	PCIE 3.0 x4
Control Protocol	NVMe
Controller	Intel custom
Memory Type	3D Xpoint
Sequential Read/Write	2.6/2.2GB/s
Read/Write IOPS	575K/550K
Warranty	Five years


The new 905p is Intel's latest premium Optane offering for consumers.
intel
Intel® Optane™ SSD 905P

Philips's new 34-inch widescreen monitor is all-around superb.

Philips 349P7FUBEB

Jack of all trades, master of some

A QUALITY PANEL with plenty of pixels. This is what a decent PC monitor is about. For sure, there are various features and frills that can amp up the experience, but get the basics right, and you're well on the way to the proverbial good PC monitor.

Enter Philips's 349P7FUBEB. In an age of 144Hz refresh, HDR capability, and quantum dot enhancement, it's a pretty straightforward proposition that majors primarily on a quality 34-inch panel. It's not pitched as an out-and-out gaming monitor, nor is it specified for content-creation professionals. Instead, it's intended as a high-quality all-arounder.

Of course, this is 2018, so that "straightforward proposition" still makes for some appealing speeds and feeds. For starters, we're talking 3440x1440 pixels, and a panel that's both superwide, with a 21:9 aspect ratio, and sports an 1800R curvature. It's also a modern MVA panel, and thus capable of 3,000:1 contrast and 117.3 percent of the sRGB color space.

Philips has also thrown in 100Hz refresh, adaptive sync, and USB-C. The former doesn't quite deliver the buttery smoothness of 144Hz, beyond which it's debatable whether the human eye can appreciate any further improvements, but it is a clear step up in slickness compared to conventional 60Hz monitors. Adaptive sync, meanwhile, is a handy little extra for smoothing out game performance when your graphics card isn't capable of cranking out triple-digit frame rates.

As for the USB-C functionality, it makes this a great choice for pairing with compatible laptops, allowing a single cable to output the display signal, charge the laptop, and attach peripherals. It's such a user-friendly solution, you won't want to go back to the old-school rats nest of cabling once you've experienced the simplicity of USB-C.

Philips has done a nice job with the industrial design, too. It's not exactly showy, but with slim bezels on three sides and a minimalist black aesthetic, it will sit on almost any desk looking high quality and quietly confident.

At this point, you should be imagining a monitor with very good all-around specs, but one that lacks a killer feature. Fire it up, and that overall impression remains. The inherent quality of the MVA panel is obvious. It may not be HDR, and the maximum brightness of 300cd/m^2 puts a practical limit on the amount of sheer visual sizzle on offer, but the high-contrast character of the panel makes for a punchy, vibrant viewing experience.

Philips has also done a solid job with the electronics. For starters, the factory calibration is probably beyond criticism, given the 349P's all-purpose remit. Gradients are impeccably smooth, and there's no sign of compression at either end of the spectrum, just plenty of detail. The user-configurable overdrive implementation is likewise excellent.

Combine that with its 100Hz capability, and the 349P has some pretty serious gaming chops. The 3440x1440 native resolution is also a good compromise between detail and GPU load. Provided you have a powerful graphics card, you can make the most of the elevated refresh rates. That pixel grid is also generous when it comes to desktop real estate.

Of course, 32-inch 4K monitors with decent MVA panels can now be had for under $400. But that doesn't buy you 100Hz refresh, adaptive sync, USB-C, or the same polish. If you just want lots pixels for desktop work, the 4K option gives more bang for your buck, but as an all-arounder that's as great for gaming as it is for lining up a trio of spreadsheets, this takes some beating. **-JEREMY LAIRD**

VERDICT **8**

Philips 349P7FUBEB

+ STANDARD MODEL Great feature set; high-quality panel.

- STRING THEORY No killer technology; fairly expensive.

$699 (estimated), www.philips.com

SPECIFICATIONS

Panel Size	34-inch
Native Resolution	3440x1440
Pixel Density	110 ppi
Panel Type	MVA
Maximum Refresh	100Hz
Response	4ms
Contrast	3,000:1
Display Inputs	DisplayPort, HDMI, USB-C
Connectivity	USB
VESA Mount	100 x 100mm
Warranty	Three years

Fnatic Streak

Just as proud as it can be of its anatomy

GAMERS ARE VERY particular people. They want specific things, certain features, particularly when they're told they want them. On the box, consummate gamer and Fnatic esportsist "JW" says his life literally depends on this keyboard, and we care deeply for his safety, so it had better be good.

It's certainly considered. Fnatic has not been shy about ladling gimmick after gimmick on to this unashamedly esports-centric keyboard. If you want to be the best, by gosh you're going to need a specific on-keyboard button to mute your mic (providing you're also using Fnatic's OP software, and a compatible headset). You're going to wonder how you ever lived without the "competition mode," which immediately dims the lights to a subtle orange and, again in conjunction with Fnatic OP, cuts down on potential on-PC distractions. And you're going to want the power of portability, so you can have your comfort-blanket keyboard with you wherever you may be.

On that last count, we have to say that Fnatic has succeeded wildly. The Streak is not the lightest keyboard, which is probably for the best, as you wouldn't want it sliding around your desk while you're doing the business, but it's certainly tight. There's next to no chin, at least without the detachable wrist rest, and minimal material on the other sides of the base gives it as compact a profile as you're likely to find in a full-size keyboard. The cable is almost industrial, encompassing both the main keyboard signal and its USB pass-through, hopefully ensuring that it won't suffer any mishaps in your bag. The key caps are attached firmly enough that you can lift the whole keyboard holding an arrow key, which should mean they won't go flying in transport, and there's internal memory for your configurations. Plus it's thin. Not uncomfortable scissor-switch thin, not in a way that makes any sacrifices, but thin.

WRIST WATCH

We should reel back a little to talk about the wrist rest, because it's a highlight that deserves its own paragraph. We've seen some atrocious excuses for tendon furniture included with some otherwise excellent keyboards recently, but this is something else entirely. It's padded, not over-soft, but definitely not rigid, and stippled with divots to collect that mid-game wrist sweat. So far so slightly gross. But there's more: It's in two parts. The metal base clips firmly on to the bottom of the keyboard with sprung clips, and the padded part nestles snugly on top in one of three grooved positions. This adjustability is something we've rarely seen, and it means large-handed gamers get their wrists looked after, rather than sliding their lower palms around on an ineffective hunk of plastic.

You have options in terms of the key switches, but this is one area where Fnatic hasn't gone totally mad with design abandon. You can select either Cherry MX Red, Blue, Brown, or, in the case of our review model, Silent Red. We probably don't need to explain how Cherry switches feel yet again, but we will: Silent Reds are (as you'd expect) very quiet, and set high enough that the key caps never bottom out, but they're dull, squashy, indefinite. There's no actuation bite; they trigger reasonably high, so they'll rarely let you down, but we prefer the tactile feel of a Brown, and suggest you select those if you're against the deafening clatter of Blues.

After the Fnatic Flick2 mouse, tepidly reviewed last issue, we were prepared for the Streak to be a streak of something quite unpleasant. But it's not. It's really rather good. The lighting's on point, the software's strong, and it's a very well designed gaming board, with a host of features that really make sense. The problem is, we wouldn't recommend it in the configuration we have under our fingers here—it's just not pleasant to type on—and it's certainly not at the cheap end of the market. Is it worth the extra bucks? Perhaps if your life depends on it. **–ALEX COX**

VERDICT **8**

Fnatic Streak

STREAK Great lighting; clever wrist rest; innovative controls.

WEAK Avoid Silent Red switches; pretty expensive.

$130, www.fnatic.com

SPECIFICATIONS

Switch Type	Cherry MX Silent Red
Form Factor	Full size
Media Keys	Yes, plus volume roller
Macro Keys	Configurable
LEDs	Per-key RGB
N-Key Rollover	87 keys
Pass-Through	Yes
Dimensions	17.3 x 5.5 x 1.4 inches
Warranty	Two years

Phanteks Enthoo Evolv X Glass

Evolution not revolution

THERE'S SOMETHING to be said for taking an already incredible design and improving upon it. Anyone can make a bad product better, but taking something that's already world-renowned, and tweaking it? Well, that's a whole other ball park. How do you take something that's already beloved by so many, and release something new, something more impressive than the last edition, without destroying its character? It's a delicate balance of subtle adjustments and re-evaluation of current features.

For that reason alone, the Evolv X is an evolutionary step in Phanteks's design philosophy, not a revolutionary one. Yet the step it has taken is huge, and at only $10 more than the original, it is still very much the massive value proposition it always has been.

Let's start with the build materials. The same 0.15-inch aluminum panels line the front and the roof. Both side panels are still reinforced tempered glass, lined with sound-dampening rubber, to help improve airflow and reduce noise. The internal panels are still thickened steel with rounded edges, and, naturally, everything has a beautiful powder-coated finish inside and out. It comes in a choice of three different colors—Satin Black, Anthracite Gray, and Galaxy Silver—although there's no non-windowed version available.

Build quality aside, Phanteks has added subtle improvements across the board to help alleviate some of the minor niggles that users had with the design in the past. The front panel gap has been extended to 1.2 inches to allow for better airflow for the front intake fans. The roof has been raised fractionally with improved airflow meshing, for better exhaust and improved twin-360mm radiator compatibility. On top of that, for the avid liquid-coolers, there's now a fill port located near the uppermost rad, along with a drain port located at the bottom-front of the chassis, behind the front panel—and, of course, Phanteks has retained its now industry-standard radiator bracket.

Then there are the new additions. The Evolv X now supports a twin system setup, with an additional ITX bracket being available to install a secondary ITX system in the roof, above your primary E-ATX one. There's the same full-length PSU cover, but it now features smarter cable management, a cleaner design, and subtle integrated RGB lighting running along its length. There's adjustable cable management via the included slidable covers located to the right of the motherboard; vertical GPU mounting is supported as standard (although you do have to buy an additional PCIe riser); there's a GPU sag support bracket that fits around the rear of the case; and speaking of the rear, there are two massive cable tidy panels to help keep those pesky 24-pin and GPU power cables out of sight and out of mind. Oh, and did we mention you can house nine 2.5-inch and ten 3.5-inch SSDs at the same time? Yup.

MORE THAN YOU CAN CHEW?

That's the biggest problem with this chassis—listing off everything you could do with it. Heck, we've got big plans for this rig, but the likelihood of us utilizing all of it? Slim to none.

So, what other criticisms can we level at this beast of a case? Well, we'll be frank, it's pretty difficult to find any flaws. Aesthetically, not a lot has changed—the front panel does look a little obtrusive now it's further forward than previously, and the chassis is a little longer to compensate, and the cable management sliders do look a bit odd if you move them across to tidy up the 24-pin perhaps. But apart from that, there's not a whole lot we can find fault with.

For the money, the Evolv X is a fantastic compilation of case design. A "best of" from the last 10 years. From its clean, crisp aluminum panels to its excessive water-cooling support and incredible price point, it's difficult to criticize. The Evolv X may be an evolutionary step in Phanteks's continued case design, but that doesn't stop it from being the revolutionary beast that it is in the market today. If you're after a premium box for your prized hardware, you won't be sorry if you invest in the X. **–ZAK STOREY**

VERDICT 9 KICK ASS!

Phanteks Enthoo Evolv X Glass

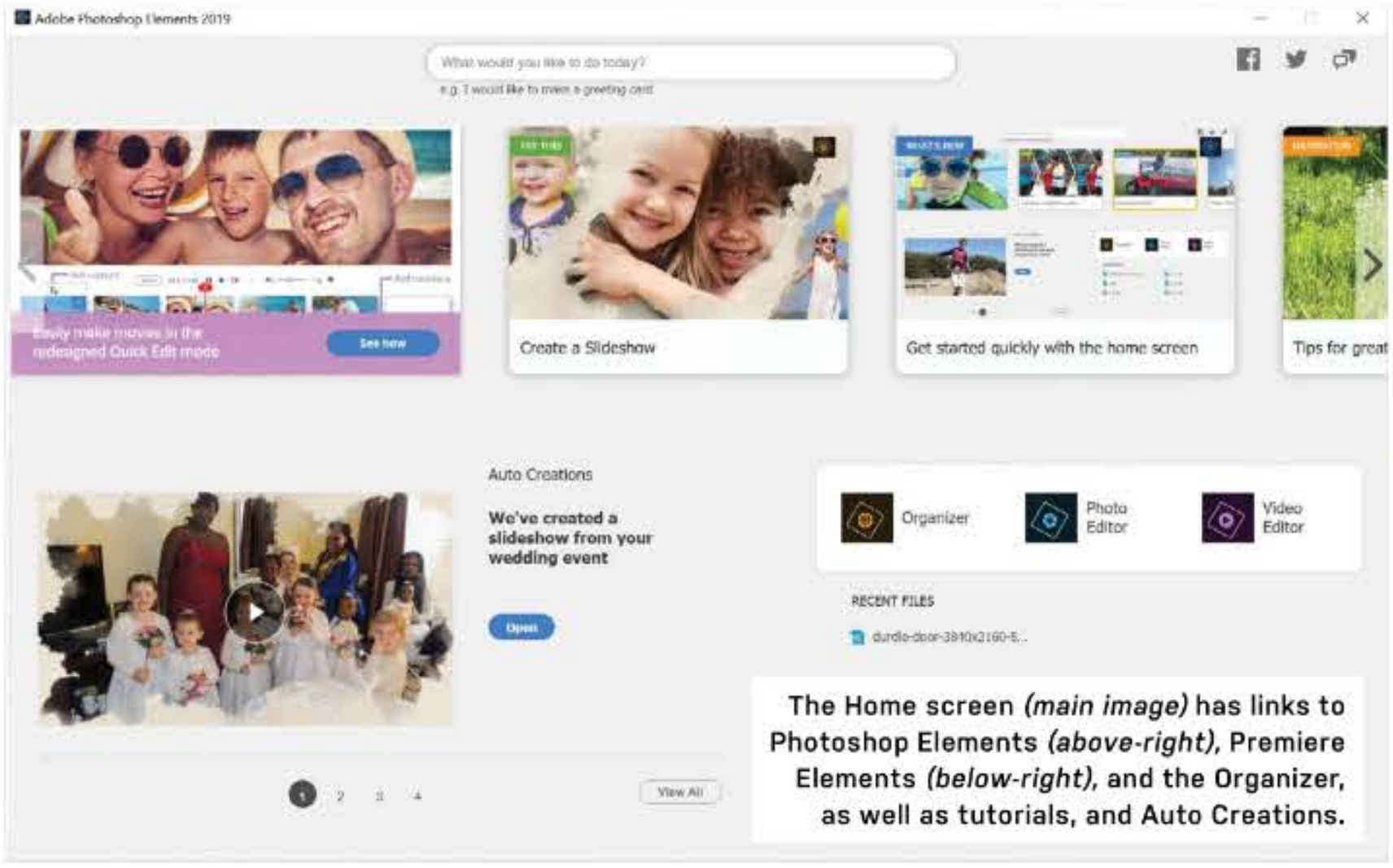
XCELLENT Price; build quality; design features; paint job; cooling support; improvements.

XCESSIVE It doesn't brew your coffee for you.

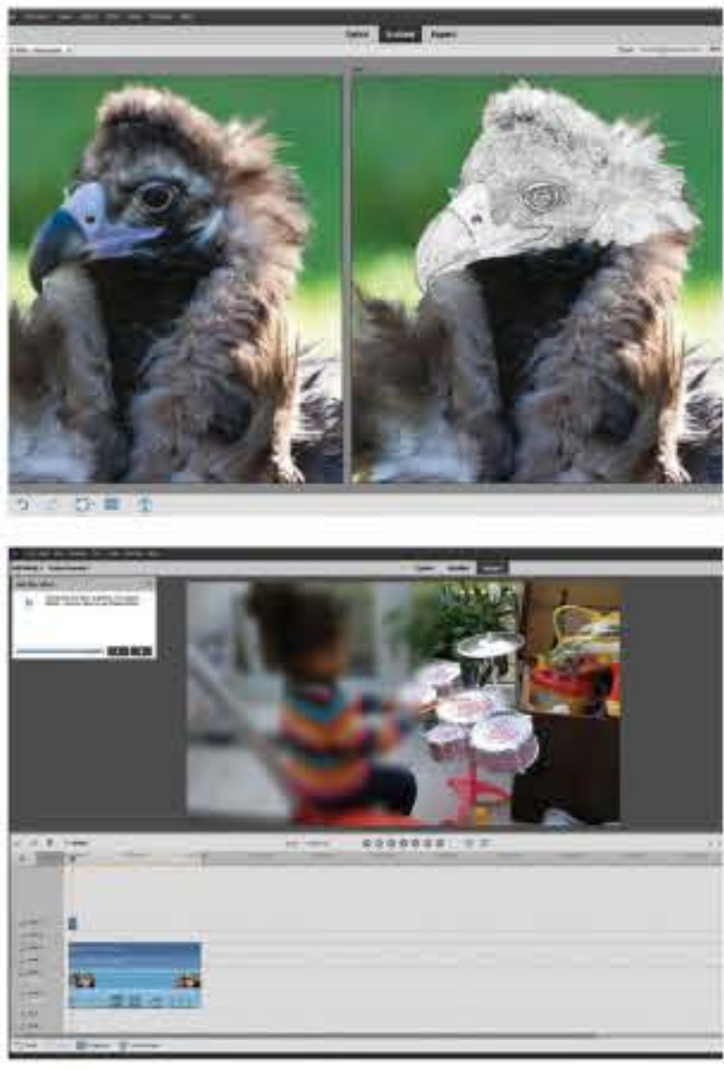
$200, www.phanteks.com

SPECIFICATIONS

Form Factor	Mid-tower
Motherboard Support	E-ATX, ATX, microATX, Mini-ITX
Colors Available	Black, gray, silver
Window Available	Only
3.5-Inch Support	10 (4 included)
2.5-Inch Support	9 (6 included)
Radiator Support	360mm roof, 420mm front, 140mm rear
Fan Support	3x 120mm roof, 3x 140mm front, 1x 140mm rear
Dimensions	9.5 x 20.5 x 20.5 inches
Graphics Card Clearance	17.2 inches
CPU Tower Clearance	7.4 inches
Weight	33lb



The Home screen *(main image)* has links to Photoshop Elements *(above-right)*, Premiere Elements *(below-right)*, and the Organizer, as well as tutorials, and Auto Creations.



Photoshop and Premiere Elements 2019

Another year, another beginner-friendly suite of apps from Adobe

FOR THOSE WHO don't want to partake of Adobe's subscription model of software ownership, the Elements suite has always offered great value. You get functional photo and video editing tools, with a lot of new-user-friendliness and automation, and plenty of templates and tutorials thrown in, too.

The pricing for Photoshop is starting to look like less of an issue, however. Elements is on an annual release schedule, buying a new version is the only way to get updates, and Photoshop Elements 2019 costs $100. A year's subscription to Photoshop CC, which also bundles the raw processing and organization app Lightroom, costs $120, and you get a constant flow of updates. Video editor Premiere is a different matter: The Elements bundle, which nets you both Photoshop Elements and Premiere Elements, costs $150. A year's sub to just Premiere Pro is $240.

At first glance, the 2019 release doesn't appear to bring much that's new to the party. The interface is still the same as it was back in version 11, released in 2012, before Adobe started putting years on things—it's dull gray and much too big, especially on a 4K screen. Its toolbars and palettes take up all four sides of its window, with areas of unused gray space that could have been used to display the information more efficiently, especially in the case of the left-hand toolbar. It's past time this was overhauled, but we're stuck with it for another year.

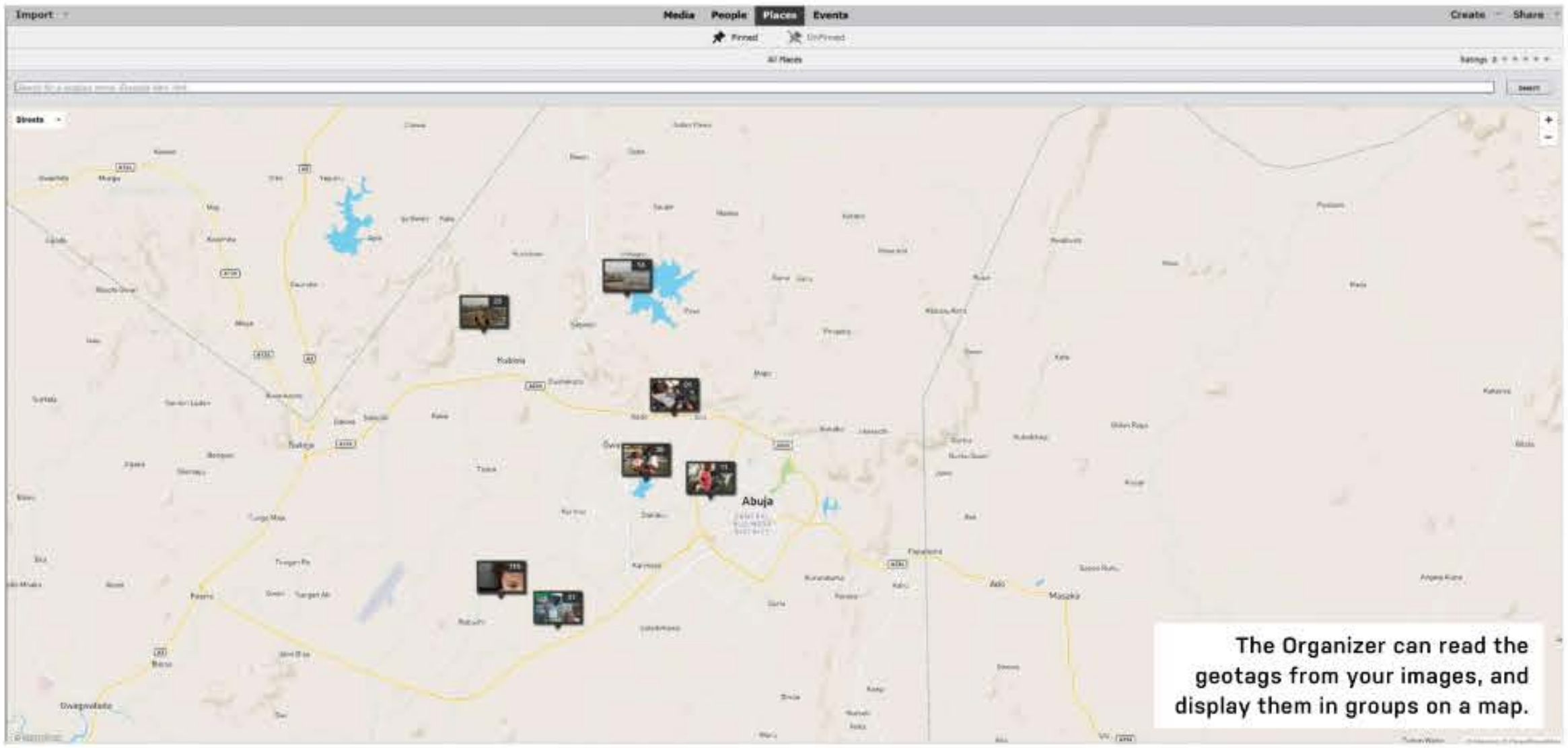
What has seen a change is the opening screen, which always offered the choice between the Editor and Organizer, but now adds much more. It's been redesigned, too, displaying links to online tips and tutorials, and even creating a slideshow from any "events" it can identify in your Pictures folder, without you asking, then offering an "Open" button. The Home screen stays open while you're using one of the Elements apps, so you can switch back to it from the Taskbar or by using a button in the app interface. It houses launch buttons for the apps, along with a list of your recently opened files, social media buttons, and a search bar for finding a tutorial for whatever it is you want to do.

The list of things within the apps that are actually new is a short one. The 2019 release naturally contains everything from 2018's apps, such as face detection, camera shake removal, haze removal, tooth whitening and eye opening, red-eye removal, and automatic object selection, and many of the improvements are now under the surface. The apps now install and run faster, although we'd never seen this as something to complain about, but those running on more modest systems may appreciate the boost. Annoyingly, especially for those with recent iPhones, HEIC and HEVC support is only found in the macOS version of the apps.

EXPERT WITNESS

In both apps, Expert mode is the same as always, offering every tool possible, and holding your hand very little. Expert mode is as close to Photoshop or Premiere CC as you're going to get from Elements, and 90 percent of the time, it's good enough. While it may not have some of the finesse or power of the pro version, there's a lot here, and it's presented in a streamlined way tailored toward beginners.

Most of the new features are found in Guided mode, which takes you through the creation of effects-laden projects using photos and videos. Adobe is proud



The Organizer can read the geotags from your images, and display them in groups on a map.

of its Sensei AI and machine-learning tech, and finds every opportunity it can to deploy it. Sensei is behind the slideshow it makes for you on the Home screen, and also powers the Auto Curation that arrived in 2018. 2019's new Auto Creations use the AI smarts, and it's more integrated into the apps as a result. In Photoshop Elements, photo collages have been redesigned, so they're created more quickly. There's an emphasis on social media sharing, so Guided mode's Fun Edits section contains a "Meme Maker" that automates the process of producing an image with text on it.

SKETCHY BENEFITS

The Partial Sketch effect is also new, and rather neat. It uses something akin to Expert mode's edge-finding Quick Selection Brush to choose areas of your image, which are then immediately painted over with a hand-drawn effect. It's a nice way of drawing attention to part of a photo, but like a lot of the Guided edits, it seems like some clever technology that won't get a lot of use.

Over in Premiere Elements, the Quick Edit mode has had an overhaul. The Timeline has been simplified, making it easier to combine your footage with music and titles, and there's a couple of new projects in Guided mode. Smart Trim, which arrived last year and uses the Sensei system, is probably the cleverest feature, as it analyzes your imported video, and attempts to automatically cut it, removing any bits it considers boring, to concentrate on the more exciting elements. Clearly, if you're in the habit of shooting long and boring movies, this feature will return only a short clip, but it's effective at removing the dull bits of setup you may capture before your subject starts speaking.

Elsewhere, there's a nice new glass pane effect for transitioning between clips, and the same Sensei-powered Auto Creations as PS Elements, but otherwise there isn't, on the surface, much difference from the 2018 edition. It's nice to see the Windows version retain the ability to burn DVDs, though—it's been removed from the macOS release.

The Organizer, Elements's media organization and tagging app, benefits from the speed increases that have been put in place, but otherwise seems exactly the same as last year's app. Its OpenStreetMap-integrated geotagging remains excellent, and along with face recognition, makes it easy to find exactly the photo you want from a large library.

SERIF SANS

The Elements apps remain excellent value, as they may last you for many years and, judging by past releases, must-buy upgrades come along only rarely. Photoshop Elements is threatened by Serif's Affinity Photo, a rival to Photoshop CC that retails for $50, but while Affinity will sell you a vector design package, too, and has a DTP app in beta testing, it has no movie editor. What it also lacks is the user-friendly presentation of Elements, and the wealth of guides and templates, although it must be said that Serif's online knowledge base is excellent.

Premiere Elements has it easier in some ways, because it's mainly competing against apps given away with digital cameras, as well as those available for free on the web. It's a definite step up from such software, the 2019 release streamlining things for beginners, while its Expert mode offers to teach you video editing—a bold claim.

Whatever your skill level, there's something for everyone here. The apps are fully featured, and perfect for the home user. While we wish they'd get an interface overhaul, some GPU acceleration, and maybe for some new features in Expert mode to trickle down from Creative Cloud, it's clear Adobe knows its target market, and has built a suite that will satisfy it. –IAN EVENDEN

VERDICT 7

Premiere Elements 2019

EDWARD WOODWARD Simple to use; plenty of templates and effects; faster than last year's.

ED WOOD Very little change from 2018; no GPU acceleration.

RECOMMENDED SPECS Dual-core 2GHz CPU (Core i7 or equivalent for 4K video editing); 8GB RAM (16GB for 4K editing).

Single app $100, bundle $150, www.adobe.com

VERDICT 8

Photoshop Elements 2019

ANSEL ADAMS Plenty of tools, and tutorials to keep you going for a long time, especially if you like memes.

PUGSLEY ADDAMS Very little change since last year; interface still far too big and gray.

RECOMMENDED SPECS 1.6GHz CPU or better; 8GB RAM.

Single app $100, bundle $150, www.adobe.com

Forza Horizon 4

Where's the fun in a road trip that sticks to the road?

DRY-STONE WALLS are built using a method that dates back to the stone age, and one that takes a lot of skill to get right. It seems a shame, therefore, to destroy quite so many of them.

Unfortunately, it's so easy to. Slide off the road as you speed through the UK (gaming's British period continues unabashed), and chances are you'll hit a dry-stone wall at an oblique angle, rocks flying into the air as your hugely expensive supercar ploughs through, largely undamaged. You'll see the AI opponents doing the same—something about being unused to driving on the left, maybe?

As you can tell, we're not in sim racing territory here. The only naturalism comes in the seasonal changes to the forests and fields you blast past at 90mph. Comparisons with *The Crew 2* are inevitable; they share the same loose festival structure, the same sort of free-roaming map studded with "missions" that can include helping filmmakers as often as straight racing, and even offer up the same car in their starting lineups. The up-front presentation here is less obnoxious, though a game streamer you meet later on is particularly inane. His missions, however, are a tribute to racing games of the past, the cars from *OutRun*, *Daytona*, and more served up for a blast through the countryside, and they're representative of the game as a whole, in a way.

SEASON'S GREETINGS

That countryside is remarkable. The game's progression takes you through all four seasons, beginning in fall, and expecting you to accrue a certain amount of "influence" before advancing. Old England might not be so famous as New England for its colors, but the feeling of time and place conjured in *Horizon 4* is strong nonetheless. Winter changes everything, the snow and ice altering the handling considerably, and requiring car upgrades across the board. Whether you buy new cars, win them, or find them in barns is up to you, but the new rides keep coming, no matter what the time of year.

Horizon doesn't care whether you race properly or smash those dry-stone walls; it rewards you for either. It doesn't care about your cars and tires, it just assumes they're in top condition. It doesn't even care whether you're having a good race, allowing you to rewind time to take a corner again if you mess up, or instantly start a race over if you feel there's no redeeming yourself—you don't even need to charge this ability up. If you're wallowing at the back of the pack, with no one to smash into, that's Clean Racing—have some points. Fishtail so badly you go through a wall, scare some sheep, drive across a field, then eventually rejoin the road just in time to crash into another racer, and that's an Awesome Skill Chain—have some points. Car damage? Don't worry about it.

It's also worth noting that, compared with certain other games reviewed this month, *FH4* runs very nicely in 4K on our GTX 1070 Ti-equipped test machine.

So, we would like to apologize to all the dry-stone wallers, and the residents of the English village of Ashbrook—we're sorry for what we did. But we were having fun. **–IAN EVENDEN**

VERDICT **9**

Forza Horizon 4

BUGATTI Looks great, plays great; eager to reward you and always offering something new.

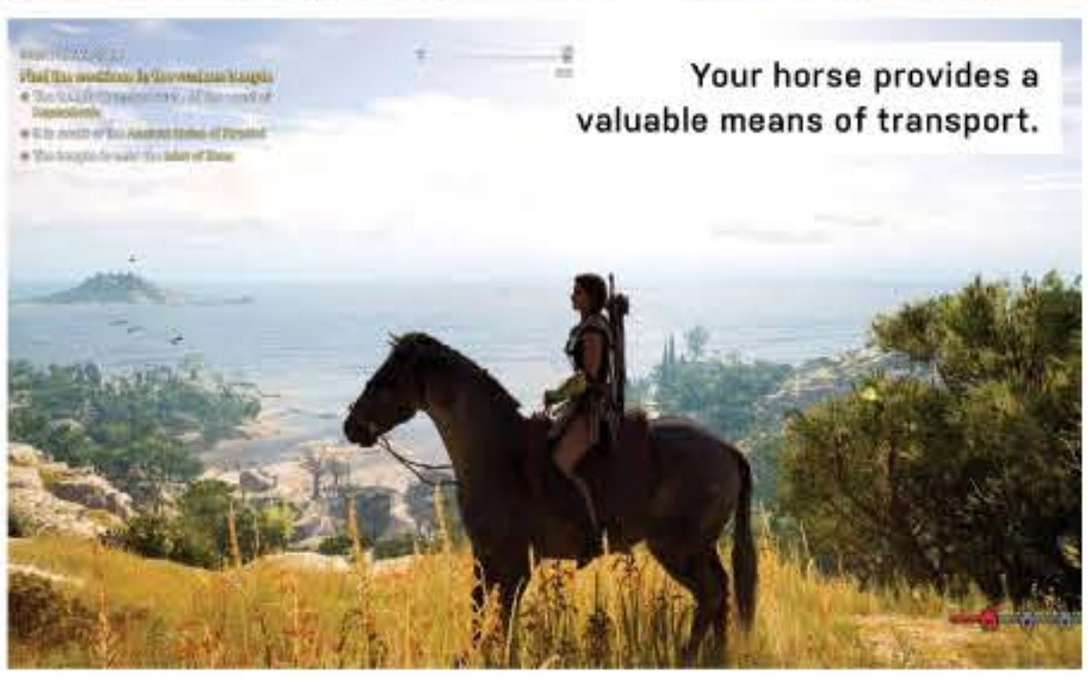
OLDSMOBILE Radio stations can get repetitive; fast travel uses in-game cash.

RECOMMENDED SPECS i7-3820; 12GB RAM; GTX 970 or RX 470

$60, www.forzamotorsport.net, ESRB: E

Your eagle scouts reveal enemies' positions and levels.

New dialog options give clues to the locations of quests.


Your horse provides a valuable means of transport.

Greece is greener than Egypt, and some of its vistas are very beautiful.

Assassin's Creed Odyssey

Greeks are bearing gifts, but there's nothing to beware

UBISOFT QUEBEC DESERVES extra turkey this holiday season, for releasing something so accomplished just a year after *Origins* began a series revamp that made it a must-play.

Odyssey moves the series back in time to ancient Greece, and opens during the battle of Thermopylae, which you may remember from the comic book and movie *300*. King Leonidas thankfully keeps his armor on, but the game has shed some of the layers that keep out curious players.

There's a choice of heroes, for one thing. There's not a huge difference—either is a refugee Spartan living in Kefalonia, making a living as a mercenary, with the same dialog options—but there are bigger changes afoot. Exploration mode is new, and billed as the expected way to play. It dispenses with map markers, giving you clues in dialog as to where you need to go next, recapping them on the map screen. It gives you more incentive to follow roads, rather than set off across country in a straight line, saving a lot of climbing and scrambling for when you get to your destination. The old way of doing things is still available, but Exploration mode brings a freshness to the game.

Elsewhere, things are much the same. You climb on things, stab people, get new gear, ride a horse, sail a boat, track down a hierarchy of local bad guys, and stab them after climbing on things, getting new gear in the process. *Origins'* RPG-style progression is back, but a new addition are the Bounty Hunters, other local mercenaries who try to take you out. The one chasing you is usually a few levels above, so must be avoided until you're powerful enough to take him on.

This system presented a problem when a bounty hunter just one level above trapped us in a cave, walking in and out as though he knew we were there, but never leaving so we could escape, and hand in the quest that would have probably leveled us up. He was practically unkillable with the gear we had, and every time we reloaded, he was back in that darn cave. Eventually, we stealthed as much as we could before running like hell—a perfectly acceptable course of action, it turned out. It could have been a bug, as we were playing before the big day-one patch that improved a lot of things, including loading times. They're still long, and the game itself is resource-hungry.

Comparing this to *Assassin's Creed Syndicate* shows how much Ubi Quebec and the game have progressed. *AC* games are now free-roaming RPGs, with huge worlds, rounded characters, and intelligent combat. When they look this good, gaming is better off for the series making changes. **-IAN EVENDEN**

VERDICT **9**

Assassin's Creed Odyssey

ATHENS Looks great; engaging characters; smooth exploration and crunching combat.

SPARTA High system requirements for 4K; long loads; some poorly placed checkpoints.

RECOMMENDED SPECS Ryzen 5 1400 or i7-3770; 8GB RAM; R9 290 or GTX 970.

$60, http://assassinscreed.ubisoft.com, ESRB: M

LAB NOTES

JOANNA NELIUS, HARDWARE STAFF WRITER

I Am My Father's Daughter

A brief history of how my dad got me into computers

MY DAD BOUGHT our first computer in 1991, a clunky IBM ValuePoint with now-ancient hardware. He bought it for himself, but before he knew it, I was spending more time playing games on it than he was. When my mom wasn't looking, he let me take over the controls for his games, such as *Lemmings*, *Arkanoid*, and the 1991 remake of *Leisure Suit Larry in the Land of the Lounge Lizards*. For whatever reason, my dad thought it would be OK to let my four-year-old self play it. Thankfully, I was too young to understand what the game was about, but the part I remember vividly was Larry walking down a dark alleyway to meet a few guys with baseball bats. That did not end well for Larry.

My love for computers and games started early, thanks to my dad. Each time he upgraded to a new computer, I got the old one, and I eventually started taking our older computers apart and putting them back together again just to see if I could do it. By high school, I grew out of my dad's preference for buying pre-built PCs, and wanted to build my own to play MMOs. Unfortunately, growing hostilities between us meant he wasn't willing to teach me, but it didn't prevent me from learning on my own, thanks to the Internet and a few awesome *Matrix Online* guildmates.

But my dad started the spark, which lead me here. As of writing this, my dad passed away no more than 48 hours ago. While we didn't have an ideal relationship, the one thing I wanted to show him was at least one article that I wrote about hardware. I wanted to know that he was proud of me. I hope you're reading this now, Dad. This is for you.

An early introduction to PC gaming from her dad led Joanna to these very pages.

JARRED WALTON

Senior Editor

By the time you read this, *Fallout 76* will be out, but I just finished spending time in the beta. One concern is how Bethesda will handle higher frame rates and vsync. You can disable vsync by editing an INI file, but going above 144fps causes the game to accelerate. In a multiplayer game, that's cheating. The irritating part is that this is a problem from previous Bethesda games, and it's something that many other games and engines have figured out. As a former software developer, this shouldn't be hard to fix. Let's hope Bethesda does the right thing, and provides proper support for FOV, ultrawidescreen, and vsync in the final game.

BO MOORE

Hardware Lead

Man, *Final Fantasy XV* is pretty. Despite being a huge JRPG fan, I skipped over the latest *Final Fantasy* at launch, but with an RTX 2080 system in for testing, I felt like the boy-band road-trip game was a great way to test out this high-end rig. It does not disappoint. Sure, the story's overly melodramatic and the gameplay's a bit of a mess, but the world looks absolutely fantastic in 4K HDR. Sprawling mountains, vast plains, the awesome waterfall city in act two. These stunning vistas render beautifully, especially after I installed the upgraded 4K texture pack. If only I could get the impeccably detailed anime boys to quit making such goofy expressions.

Editors' Picks:
Digital Discoveries

Zak Storey, deputy editor, and Alan Dexter, executive editor, share the tools that keep them on the right track

WAZE

I'm seriously into driving, and cars in particular. In fact, if it ain't computers, it's mountain bikes, and if it ain't bikes, it's cars. I grew up in a classic car family—on Ma's side, it was all about the Chevy V8s, and on Pop Storey's side, Volkswagen was the name of the game.

Now I'm hooked. There's no better feeling than getting out there on the open road. But being a tech nerd, I appreciate the gadgetry and software wizardry found in modern-day cars as much as the classic styling and engines from yesteryear.

The one thing I can't live without is Waze. It's a GPS app, piggybacking off the same technology used by Google Maps. What's great about Waze is that it's essentially a social media network. Users can mark on the map if there's a hazard in the road, what the traffic is like, whether there are police ahead, where the traffic cameras are, whether roads are closed, and even fuel prices. It also lets you know what the speed limit is, and what speed you're going. Best of all, it's free, with ads popping up only when you're stationary. It is a bit power-hungry, and obviously only passengers can input if there's anything in the road, but it's saved my bacon a ton.
$free, www.waze.com

ASUS AURA RGB LIGHTING CONTROL

With reports of failing RTX graphics cards circulating, we wanted to see if any of the cards we had were affected. The Asus GeForce RTX 2080 Ti from last month's "Build It" wasn't seeing much use, so I decided to replace the GeForce GTX 1080 in my main rig. I also shifted to a ViewSonic VP3268-4K, 32-inch 4K screen, because if you're going to stress test a $1,350 graphics card, you may as well do it properly.

To see what's happening under the hood, I installed Asus's graphics card monitoring tool, GPU Tweak II, which reveals GPU temperature, memory clock, and fan speeds. Frustratingly, it doesn't report memory temperatures, as it's on the memory front that these cards appear to be failing. This is due to a lack of sensors, though, so hardly the fault of the software.

One side effect of this is that I found myself downloading the Asus Aura RGB lighting software and, for once, not ignoring it. One lighting profile is to pulse in time with your music; it's both annoying and awesome. Unfortunately, it also adds obvious lag to YouTube videos, which is a shame, as it would have been fun to annoy the rest of the team with the light show.
$free, www.asus.com

Audio-Technica ATH-M50xBT

LAST ISSUE, I went off on a bit of a tirade against Turtle Beach's Atlas Three headset. I was unbelievably frustrated with it. Seriously, whoever decided that needing to charge a headset up and switch it on was necessary in order to simply use the analog 3.5mm jack was just nuts.

When Audio-Technica's latest press release followed, announcing that the company had finished a Bluetooth rework of arguably the most iconic pair of studio headphones in the biz, I just couldn't believe it. In fact, my response to the PR was: "Nooo! Don't cave in to the headphone-jackless phones." He went on to reassure me that audio quality wasn't affected, and the engineers who had worked on the original M50x also worked on this.

The reason this matters is that the M50x headset is nothing short of exceptional, a superstar in the industry. With impressive audio characteristics, beautiful timeless styling, and a price point making it accessible to all, it's difficult to argue with just how important a pair of cans it is.

So, first impressions? They're good, seriously good. Via Bluetooth, the sound quality doesn't waver at all, but what impressed me the most (and seemingly absent from the press release) was the inclusion of a four-pole cable and mic. Yup, these babies can be plugged in, analog-style. So, if you run out of juice, or just can't be bothered to sync up, they work just as well via that old-school standard, too. **–ZS**
$200, www.audio-technica.com

LETTERS

WE TACKLE TOUGH READER QUESTIONS ON...

> Hardware Obsolescence
> CPU Temperatures
> The End of PC Gaming

What's the best way of upgrading to a new M.2 SSD? The good news is that we show you how to do just that this very issue.

City Building

General question: I have a system with Win 10 64-bit, an Intel Core i5-4460 @ 3.2GHz, 16GB RAM, and Intel 4600 Graphics. I would like to play *Cities: Skylines*. I believe I need a video card; which one would you recommend? Do I also need to upgrade anything, such as my PSU? Thank you!

–Peter H

EXECUTIVE EDITOR ALAN DEXTER RESPONDS: If you take a quick look at the minimum hardware requirements for *Cities: Skylines*, you'll discover one interesting caveat under video card support, and that is that the game specifically doesn't support Intel Integrated Graphics. This is unusual, because while there are plenty of games around that barely run on integrated GPUs (we know, we keep trying to test with them to hit that single-digit frame rate nirvana), to say outright that they're not supported is strange. At least, it would be if it weren't for the fact that the specifications dictate that you have 512MB of dedicated video RAM, which isn't possible with integrated graphics.

If we were going to suggest a graphics card to play *Cities: Skyline* on, we'd say to look at the recommended specification as opposed to the minimum specs, as this means you should be able to run with the settings pushed up a bit (for more pretties). The main takeaway from these specs is that your graphics card of choice needs to have 2GB of dedicated video RAM. The suggestion here is for either an Nvidia GeForce GTX 660 2GB or an AMD Radeon HD 7870 2GB.

Our recommendation would be to go for something a little newer if you can, so you can play other games—something like the GeForce GTX 1050 for $130, or if that's a bit pricey, the GeForce GT 1030 for $85. These cards draw all the power they need from the PCIe bus, so you shouldn't need to upgrade your PSU, but it's worth checking beforehand, as we have no idea what PSU you have.

Drive Upgrade

Now that prices have started to come down a little for M.2 drives, I wanted to update my Samsung 960 PRO NVMe M.2 512GB to a Samsung 970 EVO 2TB NVMe PCIe M.2. I don't want to lose all of my settings and software on this drive, especially considering I just upgraded the system and did a fresh install. So my question is: What will I need to clone the existing M.2 and add the OS image to the new one? I know that Samsung has some type of software, but will I need some sort of external device to plug into the desktop?

–Daryl Austin

EXECUTIVE EDITOR ALAN DEXTER RESPONDS: Good news, Daryl: We look at this very topic this issue in our drive cloning feature. Turn to page 48 to find out more. You need a way of accessing both drives at the same time if you want to do this directly, but you can use Clonezilla to clone your original drive to a file, then write that file to your new drive after you've swapped it in.

A Moment in Time

Taken from "The Builds" in the October 2018 issue, page 98: "...approaching the realms of obsoletism." Respectfully, that is a fantastic PC. No matter what new hardware comes out, that is a machine anybody would be proud to own. Besides, there is new hardware coming out every week. Trying to stay on the fringe is simply impossible. Calling this near obsolete is not realistic in the least. Nevertheless, I still love the magazine!

–Serge Desaulniers

EXECUTIVE EDITOR ALAN DEXTER RESPONDS: One of the features of the builds at the back of the magazine

↘ submit your questions to: comments@maximumpc.com

is that they act as an overall recommendation. A key part of that is to have a machine that will last for years to come, something that is particularly true of the Turbo build, which costs upward of $3,000. When we pieced together that particular build, new hardware was on the way that directly affected that system, so it made sense to warn readers that something bigger and better was coming. You're right—had you built this monster yourself, you'd be delighted with its power... right up to the point when you realized that the core components had been eclipsed by new hardware released just a month after you'd bought everything.

A Hot Issue

Here's an interesting story I thought I would share to help others. I put this system together back in January 2018:

- AMD Ryzen Threadripper 1950X
- Enermax Liqtech TR4 280 AIO liquid CPU cooler
- Gigabyte X399 Aorus Gaming 7
- Radeon R9 Fury X
- Intel 750 800GB PCIe 3 x4 MLC SSD
- 2x G.SKILL Ripjaws V Series 16GB (4x 4GB)

All seemed to be working very well until about a month ago. First, Windows Media Player would not load sometimes, then maybe 20 minutes later it would work fine. Then other programs started doing the same thing.

I restored a backup from a few months back, taken when all was working fine. The problems persisted. I was going nuts. I looked over Event Viewer and could find nothing useful. Then, finally, last week it started shutting off randomly. It quickly got to the point where it would shut off before Windows finished booting. I thought it could be the power supply, so I subbed another one—same problem. Then I got into the BIOS before it shut off, and saw my CPU temp was climbing above 80 C in those few seconds.

In the BIOS, all fan speeds were showing good, including the pump on the Enermax Liqtech TR4 280. I then shut down and took the block off the CPU—it was so hot, I could hardly touch it. The Enermax Liqtech TR4 280 was failing, and not showing any outward signs. I ordered a CRYORIG A40 Ultimate hybrid liquid cooler and installed it, and all is running smoothly now. When I looked at the reviews of the Enermax Liqtech TR4 280 AIO liquid CPU cooler, it turns out this is happening a lot on that model. Lesson learned: When things get flaky, check your temps!

–Tom Martin

EXECUTIVE EDITOR ALAN DEXTER RESPONDS: Heat is the root cause of so many problems, that we keep an eye on temperature far more than we probably need to. As you've discovered, though, it can be tough to spot what's happening if you don't get any kind of warning from your cooler. Hopefully, your experiences will help other readers.

Game Over?

I've been testing Google's Project Stream, which is to play *Odyssey* in the Chrome browser strictly over the Internet. The quality is pretty awesome. I'm sure Google will eventually expand this concept, and I've heard that Xbox will have a streaming console as well. Do you think eventually this service will make PC hardware irrelevant for gaming?

–Tian Jin

EXECUTIVE EDITOR ALAN DEXTER RESPONDS: While streaming services certainly do have their place, there will always be people who want to have total control over their entire gaming experience. We can't see the likes of Project Stream replacing that anytime soon.

Under the Radar

I was wondering whether you would consider putting together an article that details how to use your PC more privately. In particular, you could report on which web browsers provide the most privacy when using the web, privacy settings on those web browsers, privacy settings on Window 10, the best search engines for privacy, free private email, and so on.

With all the privacy issues surrounding Facebook and Google, I personally have stopped using Google as my primary search engine, and now use Duck Duck Go instead. I also no longer use social media. I have been searching for a free private email service, and a friend recently referred me to Proton Mail, based out of Switzerland.

–Scott Cortese

EXECUTIVE EDITOR ALAN DEXTER RESPONDS: We've looked at keeping various aspects of our computing lives private before, but haven't produced a feature that covers everything. Watch this space.

[READER SPOTLIGHT]

KEEPING MODEMS AND ROUTERS COOL

I am on cable Internet using a cable modem. I recently had an experience where my Internet would stop working, and I would have to power cycle both my cable modem and my router. I noticed the cable modem was very hot to the touch, and my router was also very warm. I decided to add my own cooling to both of these.

I wanted to share my story for anyone else who may be experiencing the same thing. It was fairly easy to cool these using standard 120mm computer case coolers. I was able to use a standard 12V power supply, the kind that is used for video security cameras. All of the parts are available from Frys Electronics, and are reasonably priced.

Now, both my cable modem and router are cool as a cucumber, and I haven't had any issues with losing my Internet connection since I added the cooling.

–Roger "The Cooling Man" Myers

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THE BUILDS

BUDGET

INGREDIENTS

PART		PRICE
Case	BitFenix Nova TG	$46
PSU	450W Corsair CX450	$48
Mobo	ASRock AB320M-DGS	$50
CPU	AMD Ryzen 3 1200	$110
GPU	Gigabyte GeForce GTX 1050 2GB	$130
RAM	8GB (2x 4GB) Team T-Force Dark @ 3,000MT/s	$80
SSD	120GB Adata Ultimate SU650 2.5-inch SSD	$28
HDD	1TB Seagate BarraCuda ST1000DM010 HDD	$45
OS	Ubuntu Desktop Linux 18.04 LTS 64-bit	$16

Approximate Price: $553

NO CHANGES. There's been nothing but price drops this issue in our budget build, and a $17 saving is great if times are hard. There's little we'd change here: The Ryzen 3 1200, although last-gen, is a strong entry-level processor, and the AB320M-DGS with a BIOS upgrade will happily support any Ryzen 2 part, if you're interested at a later date. The one thing we're not super-happy with is the GPU. Gigabyte makes some mighty fine cards, but Nvidia's GTX 1050 GPU is just not powerful enough for our 1080p aspirations. The difference between that and the GTX 1060 3GB is staggering, and worth the extra $60–$80 if you can stretch that far. If gaming isn't your thing, you could forsake the GPU, and replace the Ryzen 3 1200 with a Ryzen 3 2200G. Its integrated graphics will be able to drive your everyday content at 1080p just fine. Just bear in mind you'll struggle with more demanding graphical tasks.

MID-RANGE

INGREDIENTS

PART		PRICE
Case	Fractal Design Meshify C	$76
PSU	550W EVGA SuperNOVA 550 G3 80+ Gold	$68
Mobo	Asus ROG Strix B450-F Gaming	$122
CPU	AMD Ryzen 7 2700	$270
Cooler	Corsair Hydro H100i Pro 240mm RGB AIO	$120
GPU	Gigabyte GeForce GTX 1070 Ti	$390
RAM	16GB (2x 8GB) G.Skill Aegis @ 3,000MT/s	$124
SSD	250GB Samsung 970 Evo M.2 PCIe SSD	$88
HDD	1TB Seagate BarraCuda ST1000DM010 HDD	$45
OS	Windows 10 Home 64-bit OEM	$100

Approximate Price: $1,403

$2 SAVINGS THIS ISSUE, and no changes to the mid-range, either. Intel may be stretching its legs in this market segment, but it just doesn't hold that value position right now, and that's a biggy for us. We've always been about maximum power—it can be as expensive as you like, but if it's not good value at that price, it's time to throw it out. We're still waiting to see a 9th-gen Core i5 sample from Intel, so for the time being, we're sticking with our Ryzen 7 2700. It's a kick-ass processor, especially for those into overclocking, and AMD's Ryzen Master software makes the job a cinch, and is something we regularly turn to if we can't be bothered to keep booting back into the BIOS. The GTX 1070 Ti also provides a fantastic amount of performance for the price still—expect an easy 60fps at 1440p across most titles. It's a little like a refined GTX 1080, just using lower-spec memory, and with a few more CUDA cores disabled.

UPGRADE OF THE MONTH

PHANTEKS ENTHOO EVOLV X GLASS

Sometimes, it's not about power or the experience, it's about appearance. If you've got a raggedy old case that could do with an update, there's no better chassis out there right now than the Evolv X. This evolutionary icon is nothing short of awe-inspiring, with extensive cooling support, dual system compatibility, sophisticated RGB LEDs, and enough clever touches to make building in it a dream.

Head to Pinterest, PC Part Picker, or Instagram, type in "Evolv X," and you'll see all manner of gaming setups featuring a Phanteks Evolv, and for $200, what have you got to lose? We'll be using our sample in an upcoming liquid-cooled behemoth, featuring an RTX 2080 Ti and a whole heap of EKWB parts. That said, it's equally at home with air cooling, server rigs—with its massive 19 supported hard drive bays—or casual gaming.

$200, www.phanteks.com

IT LOOKS LIKE we don't have any major changes to our Turbo build this issue, either. The ones we have tweaked—PSU, GPU, and RAM—are all just variants of ones we had last issue. We've opted for a $10 more expensive Corsair RM power supply, the white variant, as it comes with pre-sleeved white cables; a 32GB kit of RGB Trident Z memory at 3,000 MT/s, as opposed to last issue's 3,200 MT/s (no longer available at that price); and the RTX 2080 has transformed into a $10 cheaper Gigabyte variant, again with a white color combo to match the PSU, cables, memory (if configured), and mobo.

We're still left with a $20 saving overall, which never hurts. There's a few obvious changes we could have gone for. The 24-core Threadripper 2970WX, for instance, would be an obvious contender, but because it's more of a workstation part, as opposed to a gaming or mainstream part, we're reluctant to recommend it, because these builds are designed around that all-arounder principle. The 2970WX does take some tweaking to get it running right; it doesn't have immediate plug and play capability, and that's a big deal for us. Storage is pretty strong here, though, as is the cooling. One thing we would recommend on that front is potentially investing in a bit of extra case fan cooling, because both the RTX 2080 and the 2950X can punch out some serious heat. In hotter parts of the country, that may be a necessity.

For more of our component recommendations, visit www.maximumpc.com/best-of-the-best

INGREDIENTS

PART		PRICE
Case	NZXT H700i	$172
PSU	Corsair RM750x White 750W Gold Certified **NEW**	$110
Mobo	Asus Prime X399-A	$300
CPU	AMD Threadripper 2950X	$900
Cooler	Enermax Liqtech TR4 II 240mm RGB AOI	$133
GPU	Gigabyte GeForce RTX 2080 Gaming OC White **NEW**	$800
RAM	32GB (4x 8GB) G.Skill TridentZ RGB 3000 **NEW**	$302
SSD	512GB Samsung 970 Pro M.2 NVMe	$198
HDD	2x 2TB Seagate BarraCuda ST2000DM006	$120
OS	Windows 10 Home 64-bit OEM	$100
Approximate Price:		**$3,135**

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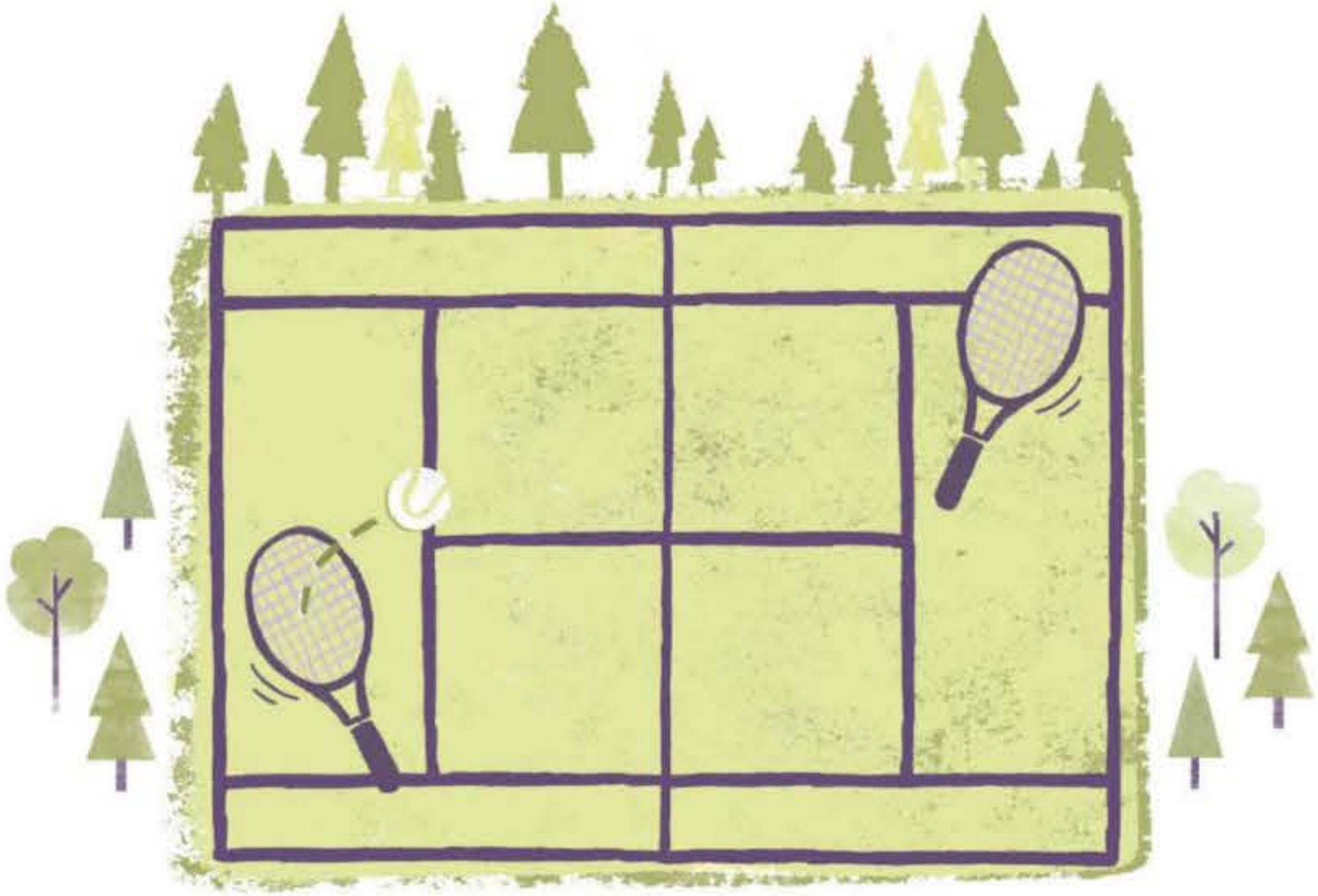

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